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DOCTORAATSPROEFSCHRIFT

Essays on measuring and improving outcomes and costs of care pathways. A Value-Based Healthcare perspective.

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Abbreviations

ABC	Activity-Based Costing
ATC	Anatomical Therapeutic Chemical classification system
BHIR	Belgian Integrated Health Record
CFO	Chief Financial Officer
CPP	Costs Per Patient
CT	Computed Tomography
DBC	Diagnosis Treatment Combination (Diagnose Behandel Combinatie)
DRG	Diagnosis Related Group
EHDS	European Health Data Space
EORTC	European Organization for Research and Treatment of Cancer
EXPH	Expert Panel on effective ways of investing in Health
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GP	General Practitioner
HDA	Belgian Health Data Agency
HH	Home hospitalization
ICHOM	International Consortium for Health Outcomes Measurement
KCE	Belgian Health Care Knowledge Centre
MD	Medical Doctor
NHI	National Health Insurance
NHS	National Health Service
NMR	Nuclear Magnetic Resonance
OECD	Organization for Economic Co-operation and Development
OMOP	Observational Medical Outcomes Partnership
OR	Operating Room
PET	Positron-Emitting Tomograph
PLICS	Patient Level Information and Costing System
PREM	Patient Reported Experience Measure
PRO	Patient Reported Outcome
PROM	Patient Reported Outcome Measure
RQ	Research Question
SDG	Sustainable Development Goal

SDM	Shared decision-making
SOC	Standard of Care
SOI	Severity of Illness
TDABC	Time-Driven Activity-Based Costing
VBHC	Value-Based Healthcare
VIKZ	Vlaams Instituut voor Kwaliteit van Zorg
VZN	Vlaams Ziekenhuisnetwerk KU Leuven VZW
WHO	World Health Organization

Introduction

In this general introduction, we lay out the challenges that formed the basis for conducting this PhD research. We then describe two frameworks that aim to improve the health system: the quintuple aim and Value-Based healthcare (VBHC). Thereafter, we focus on VBHC and, more specifically, on the recommendations in implementing VBHC. Finally, we outline the research questions that will be addressed in this PhD study.

Challenges

This doctoral research was initiated because of various evolutions and challenges faced by the healthcare sector. Firstly, the aging population and advancements in treatment options have resulted in a rise in the number of individuals with chronic illnesses and multimorbidity (Uijen & van de Lisdonk, 2008). This increase brings new challenges in terms of organization of care, as the current organization of care for individuals with complex health conditions remains fragmented within health systems and there is a need for better coordination of care across facilities (primary healthcare, hospital care and welfare) (OECD, 2022).

Secondly, very few care providers have assessed the clinical outcomes of the care they deliver and there is little transparency about the quality of care provided. The Organization for Economic Co-operation and Development (OECD) estimates that one in 10 patients are adversely affected during treatment by preventable errors, which accounts for 10% of hospital expenditure allocated to correct these errors (OECD, 2017). Moreover, international studies demonstrate substantial variations in outcomes among hospitals when measured and compared in a standardized way (EIT Health, 2020). This variation in outcomes reveals other challenges. First, there is the issue of underuse in healthcare, characterized by the failure to adequately detect, treat, or prevent diseases. There is also the challenge of overuse, which results in waste that does not add value to patient outcomes. Overuse can even result in patient harm through overdiagnosis, overtreatment and side effects of unnecessary care. (Expert Panel on effective ways of investing in Health, 2019)

Thirdly, there is an overall ambition to reduce healthcare costs. In Belgium, in 2022, healthcare costs were 10.9% of gross domestic product (GDP), which is higher than the OECD average of 9.2%. In addition, Belgium has a high level of inpatient care (curate-rehabilitative care in inpatient and day care settings). In Belgium, 37% of all health expenditure in 2021 was intended to be used for inpatient care. According to the OECD, this is the fourth-highest percentage among the OECD countries, after Romania, Greece, and Bulgaria, and 9% higher than the OECD average (OECD, 2023b). Nevertheless, Belgian hospitals face very low margins and in 2022, the average current result of the general hospitals was for the first time loss making (MAHA, 2023). Faced with these challenges, in 2022 the Belgian Minister of Public Health announced a major reform of the hospital organization and financing (Vandenbroucke, 2022). The goal is to create more and better healthcare with the available resources, a better care experience, a less stressful working environment, and greater social equity in healthcare.

Fourth, digitalization and technological innovations offer new opportunities for patients and care providers in terms of communication, data sharing, diagnostics, and the organization of care.

Improving the healthcare system: quintuple aim and Value-Based Healthcare

To improve the healthcare system, several strategies and frameworks have been developed. Within the scientific literature, two of those frameworks have received substantial attention: the triple aim (7.891 results in PubMed) and Value-Based Healthcare (18.411 results in PubMed).

The concept of the triple aim was initially introduced by Berwick et al. (2008) with the objective of pursuing three simultaneous aims: enhancing population health, improving the care experience, and reducing costs. To achieve these aims, certain conditions must be met: (1) enrollment of a well-defined population, (2) a commitment to universality for all members of that population, and (3) the establishment of an accountable organization, acting as an integrator, which assumes responsibility for accomplishing all three objectives on behalf of the population (Berwick et al., 2008). Over time, the quintuple aim expanded upon this framework by incorporating two additional goals: improving provider satisfaction and advancing health equity (Nundy et al., 2022).

Simultaneously, VBHC was formulated as a strategy to improve healthcare and to maximize value for patients. Porter (2010) defined value as the health outcomes achieved relative to the cost of achieving those outcomes. This value is created by the combined efforts of all providers over the full cycle of care for the patient's medical condition. Therefore, outcomes and costs should be measured for the full cycle of care and the results should be used to improve care delivery.

In a European Commission Report of the Expert Panel on effective ways of investing in Health (EXPH), this interpretation of value was perceived as too narrow and too focused on the providers' perspective. In the Expert Panel's opinion, this definition misses the health system, patient-centered approach, especially as aspects of equity are missing. Therefore, the EXPH formulated a broader definition of VBHC: *"VBHC is a comprehensive concept built on four value-pillars: appropriate care to achieve patients' personal goals (personal value), achievement of best possible outcomes with available resources (technical value), equitable resource distribution across all patient groups (allocative value) and contribution of healthcare to social participation and connectedness (societal value)"*. By formulating this broader and more comprehensive definition, they include important aspects, such as quality of care, patient experience, patient preference, population health, wellbeing outcomes and sustainability (Expert Panel on effective ways of investing in Health, 2019).

In comparing these definitions, Ahaus (2020) observed that the unit of analysis is different in both definitions: the care pathway versus society. In his opinion, the definition of VBHC formulated by Porter (2010) is valuable if it addresses the operational improvement of the whole care process from the patient's perspective.

In this PhD research, we want to learn how these VBHC principles can be implemented in practice. Therefore, the subsequent section of this introduction aims to provide an overview of components in implementing VBHC described in the scientific literature.

Implementation of Value-Based Healthcare

Porter and Lee (2013) described different stages in implementing VBHC: (1) organizing care into integrated practice units, (2) measuring outcomes and costs for every patient, (3) moving to bundled payments for care cycles, (4) integrating care delivery across separate facilities, (5) expanding excellent services across geography, and (6) building an enabling information platform.

As value was defined as the health outcomes achieved relative to the cost of achieving those outcomes, a methodology was formulated to measure the outcomes and costs of the care delivered. The goal to measure outcomes resulted in the foundation of the International Consortium for Health Outcomes Measurement (ICHOM) (Porter et al., 2016). ICHOM's aim is to create international standard sets of outcomes per pathology that reflect what matters most to patients and to enable global outcome comparison and improvement of care delivery. To date, 46 international sets have been created (ICHOM, 2022). In order to calculate costs of care pathways in the value equation, time-driven activity-based costing was proposed as the appropriate methodology (Kaplan, 2014; Kaplan & Porter, 2011; Kaplan et al., 2014).

The EXPH also formulates recommendations to implement VBHC. They advise formulating a strategic long-term plan for the effective reallocation of means towards high-value care. Accordingly, six recommendations were formulated: (1) awareness of health as an essential investment in an equal and fair European society and to achieve the United Nations' Sustainable Development Goal (SDG) of universal health coverage; (2) research and development on appropriateness and unwarranted variation of healthcare, including quality registries; (3) set up learning communities for benchmarking, exchange of experience, piloting and evaluating; (4) encourage health professionals to take responsibility and to feel accountable for population health; and (5) support patients' initiatives in shared decision-making and the creation of quality information. (Expert Panel on effective ways of investing in Health, 2019)

In addition, Ahaus (2020) emphasized the importance of patient involvement in the implementation of VBHC on two levels. Firstly, there is the importance of involving patients in making choices in their own care, through shared decision-making or discussing information from patient reported outcome measures (PROMs) with their healthcare provider. Secondly, patients' involvement is crucial in the quality improvement of the care process, as they know best what is important in delivering VBHC.

Recently, three additional implementation models were described in the scientific literature (Cossio-Gil et al., 2021; EIT Health, 2020; van der Nat, 2022). Cossio-Gil et al. (2021) proposed a roadmap consisting of six phases for implementing VBHC. The first phase is to prepare the whole organization for the implementation of VBHC by setting up a strategic plan, including evaluation and follow-up. The next five phases cover the implementation of VBHC for a specific care pathway: preparation, design, building, implementation, and evaluation and improvement. Enablers are organizational engagement and governance, communication, training, leadership, patient engagement and benchmarking transparency. EIT Health (2020) put the focus on the measurement and improvement of outcomes to achieve value. They outlined five key dimensions in most VBHC initiatives: (1) measuring processes and outcomes through a scorecard and data platform, (2) benchmarking teams through internal and external reports, (3) investing resources and creating outcome-based initiatives, (4) organizing improvement cycles through collective learning, and (5) aligning internal forces and collaborations with external partners. van der Nat (2022) added to this the recommendation to integrate information on treatment

outcomes as part of the conversation between a patient and his physician for shared decision-making (SDM).

In summary, the recommendations for implementing VBHC highlight several crucial aspects: (1) measuring outcomes, costs and variation in healthcare, (2) benchmarking and setting up learning communities, (3) integrating care delivery over the full cycle of care, and (4) including the patients' perspective in shared decision-making and quality improvement. In this PhD research, we want to learn how we can bring these aspects into practice through specific case studies. Other aspects of VBHC formulated by EXPH, like universal health coverage and population health, are important, but are beyond the scope of this PhD research.

The objective of this research

The objective of this research is to learn how the VBHC principles can be implemented in practice in order to improve the care delivery in the Belgian healthcare system. Therefore, the problem definition of this PhD research was formulated as follows.

> **How can we measure costs and outcomes of care and how can we use this information to improve outcomes and costs?**

This problem definition was divided into different research questions (RQs):

RQ1: How can we measure outcomes of care?

In Chapter 1, we evaluated whether it is feasible to collect and follow-up clinical outcomes and PROMs. Therefore, we evaluated the implementation of outcome measurement for lung cancer patients in a specific case study in AZ Delta. Inspired by the principles of VBHC, this department standardized care pathways, defined outcomes and implemented a digital platform for the collection of clinical outcomes and PROMs. Also, a follow-up of the PROMs by the multidisciplinary care team was put in place and this information was integrated into the conversation between the patient and his care providers.

RQ2: How can we measure costs of care?

The measurement of costs of care is a key component of VBHC. With this research question, we investigated the methodologies to calculate the costs of care. This is reported in Chapter 2.

RQ3: Can we set up a benchmark of processes and costs of care in Belgian hospitals?

Benchmarking of processes, outcomes, and costs of care is seen as a main component in the implementation of VBHC. Therefore, in this second chapter, we investigate whether it is feasible to set up a benchmark between hospitals and what the barriers and learnings are. To that end, a research project was set up to benchmark outcome, process, cost and revenue data of Flemish hospitals. The result of the first pilot of this benchmark on process and cost data in six Belgian hospitals is reported in Chapter 2.

RQ4: What can we learn from benchmarks and how can it improve care delivery?

Learning from each other and setting up improvement cycles is a crucial step in improving value. As the implementation of a benchmark was the goal of RQ3, RQ4 sought to determine whether this benchmark helped to improve care delivery. This research question is also included in Chapter 2.

RQ5: What is the impact of optimizations in the care process on costs and outcomes?

The purpose of RQ5 was to determine the impact of optimizations in the care process on costs and outcomes. We investigated a concrete case study, the onco@home-project, in which two home hospitalization (HH) models were implemented. In the first model, blood drawing and monitoring prior to intravenous therapy were performed by a trained home nurse at the patient's home the day before the visit to the day hospital, rather than in the hospital on the day itself. This care model was implemented by three Belgian hospitals and three home nursing organizations. In the second model, the administration of two subcutaneous treatments was partly provided at home instead of in the hospital. This was implemented in one hospital.

Chapter 1: How can we measure outcomes of care?

Based on: *Misplon, S., Marneffe, W., Himpe, U., Hellings, J., & Demedts, I. (2022). Evaluation of the implementation of Value-Based Healthcare with a weekly digital follow-up of lung cancer patients in clinical practice. European Journal of Cancer Care, e13653-e13653. doi:10.1111/ecc.13653*

Evaluation of the implementation of Value-Based Healthcare with a weekly digital follow-up of lung cancer patients in clinical practice

Abstract

Objective

The aim of this study was to evaluate the implementation of Value-Based Healthcare principles for lung cancer patients in a large Belgian hospital. This hospital implemented a digital platform for the collection of patient-reported outcomes and the standardization of care pathways. Also, a follow-up by the multidisciplinary care team was put in place.

Methods

The evaluation was done by employing a mixed method approach with data-analysis of all included patients (n=201), a pilot study (n=30), and semi-structured interviews with the care team (n=5).

Results

Overall, 95% of all lung cancer patients of two thoracic oncologists agreed to participate in the digital follow-up during the period January 2018–September 2020 (201 participating patients). The response rates of those patients were high: 92% of the weekly questionnaires and 90% of the 6-weekly ICHOM questionnaires were responded. Based on the pilot study, we conclude that questions are clear, and the platform is user-friendly for 90% of patients in the pilot. The interviews revealed that the weekly follow-up has a positive impact on the patient–provider communication and makes it easier to discuss psychological and palliative care needs.

Conclusion

This study shows a successful implementation of Value-Based Healthcare with weekly digital follow-up.

Introduction

Lung cancer is a serious and common type of cancer that has very low survival rates. Both in Belgium and in Europe overall, lung cancer was the most frequent cancer-related cause of death in 2016. Patients with lung cancer often face a high burden, with disease- and treatment-related symptoms that have a high impact on their Quality of Life. Both physical and psychosocial problems are often under-recognized by physicians or not expressed by patients. (Atkinson et al., 2016; Laugsand et al., 2010; Ugalde et al., 2012)

Patient-reported outcome measures (PROM) are increasingly used in clinical practice to detect those physical and psychosocial problems, to improve symptom control, to track patient progress and to enhance communication with patients (Chan et al., 2019). A PROM can be defined as "a measurement based on a report that comes directly from the patient about the status of a patient's health condition, without amendment or interpretation of the patient's response by a clinician or anyone else" (FDA, 2009). In a randomized controlled trial on symptom monitoring with PROMs during routine cancer treatment including lung cancer, the weekly collection of PROMs resulted in an improved health-related Quality of Life, a reduction in emergency room admissions and hospitalizations and quality-adjusted survival (Basch, 2016). Furthermore, multiple systematic reviews have provided strong evidence that the use of PROMs improves symptom control (Kotronoulas et al., 2014), patient–provider communication (Chen et al., 2013), and patient satisfaction (Chen et al., 2013) (Kotronoulas et al., 2014). PROMs are often collected by a digital health solution. Research shows that the benefits of PROMs are not only obtained by the assessment of outcomes, but also by the appropriate management of the responses. Therefore, these digital health solutions need to be integrated into healthcare team practices (Aapro et al., 2020).

Value-Based Healthcare (VBHC) aims to maximize the value for patients by achieving the best outcomes at the lowest cost (Porter & Lee, 2013). Cossio-Gil et al. (2021) see 4 important areas in the roadmap for implementing VBHC: (1) Organize care pathways, (2) collect a set of outcomes, including clinical outcomes and PROMs, (3) build an information platform and (4) actively use short-term and long-term outcomes for clinical decision and for improving care. Inspired by the principles of VBHC, a large Belgian hospital decided to optimize the care delivery for lung cancer patients. Therefore, they focused on those 4 areas and standardized care pathways, defined outcomes and implemented a digital platform for the collection of clinical outcomes and PROMs. Also, a follow-up of the PROMs by the multidisciplinary care team was put in place.

Recent reviews concluded that future research should assess the applicability of PROMs in routine clinical practice (Aapro et al., 2020; Cavanna et al., 2020). Therefore, the present article presents the results of a study conducted to evaluate the digital collection and follow-up of PROMs. The aim of this research is to improve the knowledge on optimizing care delivery by using PROMs in routine clinical practice.

Methods

In this section we will first discuss the methods used for the evaluation of the digital follow-up of lung cancer patients in a large Belgian hospital, and then elaborate on the implementation process that has been evaluated.

A. Methods used for the evaluation of the digital follow-up of lung cancer patients

For the evaluation, we used the Framework for Implementation Outcomes Proctor et al. (2011), which is composed of eight types of Implementation Outcomes: feasibility, acceptability, adoption, appropriateness, fidelity, implementation cost, penetration, and sustainability.

Study design

The evaluation was conducted employing a mixed method approach by: (1) data analysis of all included patients in the digital platform for the period January 2018–September 2020, (2) a pilot study on the feasibility and (3) semi-structured interviews with the care team.

1. Data collection of all included patients

The digital collection and follow-up of PROMs started in January 2018 for all lung cancer patients treated by the two thoracic oncologists working on the main campus of the hospital. To evaluate the implementation, data on response rates, alerts, and patient characteristics were collected of all included patients during the period January 2018–September 2020.

2. Pilot study

A pilot study for 30 patients was set up during the period from February to December 2019 to evaluate the feasibility of the digital weekly follow up of PROMs. For reasons of comparison and consistency, only patients at the start of their Stage IV treatment were recruited in this pilot. The study period lasted six months, from the start of the Stage IV treatment. Patients at the start of their Stage IV treatment were asked by the oncology nurse to participate. Patients were eligible if they were diagnosed with Stage IV lung cancer, spoke sufficient Dutch, and were willing to participate. Patients were randomly assigned to two arms by simple randomization. In the intervention arm, 15 patients received a weekly questionnaire. Alerts were sent to the multidisciplinary care team, who undertook follow-up actions. In the control arm, 15 patients received the standard care pathway without weekly questionnaires and without automatic alerts to the care team. The standard care pathways and the care team were the same in both groups.

In this pilot study, the weekly follow-up was evaluated in three different ways to ensure that all the relevant information was gathered through various channels. (1) At the beginning and end of the study period, patients in the intervention arm received a validation questionnaire. (2) In addition, five patients in the intervention arm were interviewed in a semi-structured way in June 2019. (3) The care team in the hospital registered the workload of the team for all included patients in the pilot study during these six months. They registered all contacts with the included patients, such as phone calls, consultations, multidisciplinary team meetings, and emails and the time spent on every contact in both arms.

3. Semi-structured interviews care team

Subsequently, semi-structured interviews were conducted with five members of the multidisciplinary care team in June 2020 – namely, an MD thoracic oncologist, oncology nurse, psychologist, palliative support, and dietician. This way, a breadth of professional perspectives was included in the interviews. The questions of the interviews are included in the supplementary information.

Data analysis

The outcomes were analyzed using descriptive statistics and calculations were performed in Excel. Subsequently, Stata was used to analyze the correlation between the response rates and alerts generated and the patient characteristics.

Ethics

The study protocol was approved by the Medical Ethical Committee of the hospital. Participants in the pilot study provided written informed consent. The dataset for the analysis of the response rates during the period January 2018–September 2020 only contained pseudonymized data.

B. Implementation process of VBHC with weekly digital follow-up of PROMs

The implementation process consisted of three important milestones. First, in January 2017, a multidisciplinary care team was set up and standard care pathways were defined for every stage of the disease and type of treatment. Second, in January 2018, the care team started to use a digital platform for the collection of PROMs and the standardization of care pathways. Third, in February 2019, the care team started with the adapted version of the weekly questionnaire based on the international standard PRO-CTCAE (explained further).

Figure 1 provides an overview of the implementation milestones and the sequencing of the activities performed to evaluate the implementation.

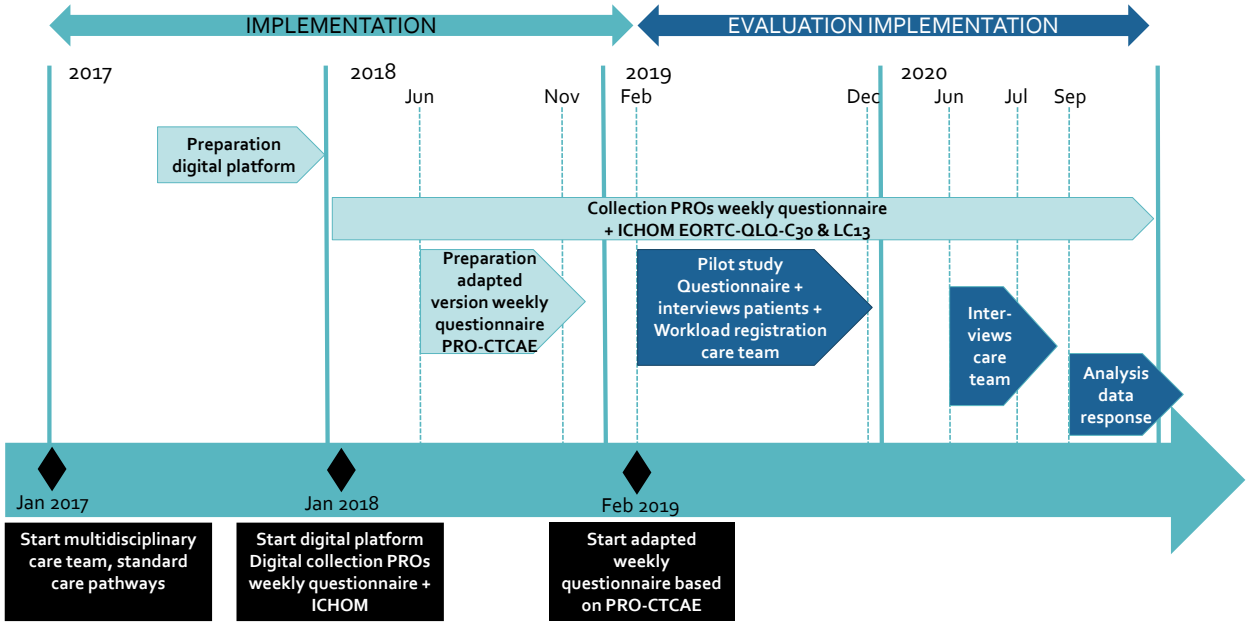


Figure 1: Implementation milestones and overview of methods for evaluation

Multidisciplinary care team and standard care pathways

A multidisciplinary care team was introduced for the follow-up of the treatment. This care team consists of two MD thoracic oncologists, a dietician, a psychologist, a dedicated lung cancer oncology nurse, two nurse unit managers and pastoral, palliative, and social support. During weekly team meetings, every new diagnosis, as well as specific cases or messages from the weekly digital follow-up of PROMs that need attention, are discussed.

The care team defined standard care pathways for every stage and type of treatment in 2017. Figure 2 shows an extraction from these standard care pathways. Agreements were made about the sequencing of activities: appointments with different physicians (thoracic oncologist, general practitioner (GP), surgeon, radiotherapist, etc.), diagnostics, registration of clinical outcomes, digital questionnaires, etc. Also, the role of the GP was made clearer in the care process. Previously, the role of the GP had not been clearly defined and patients always contacted the hospital in case of questions. Now, in the overview of care activities, patients can see when they need to visit the GP. Also, patients are advised to contact the GP first in case of adverse events; in this way, the GP is involved in the whole care process of lung cancer patients.

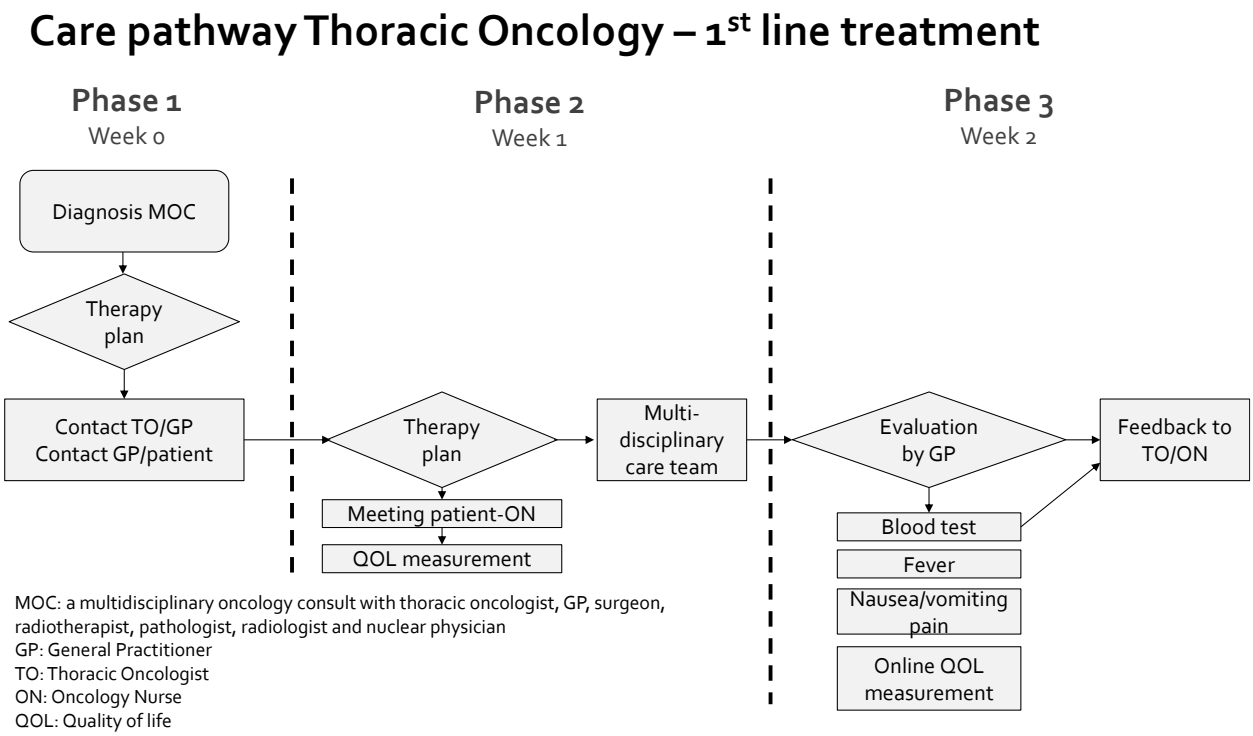


Figure 2: Extraction from the standard care pathways

Digital collection of PROMs

Method of data collection

Since 2018, the standard care pathways are supported by a digital platform developed by a private company (Awell Health). This platform enables the digitalization of care pathways and the collection of PROMs by e-mail. The oncology nurse provides a personal introduction to every patient at the start of the treatment. A telephone follow-up by the oncology nurse is also in place in case of non-response.

Content of data collection

WEEKLY DIGITAL QUESTIONNAIRE: ADVERSE EVENTS AND PSYCHOSOCIAL CARE NEEDS

At the start of the digital follow-up (January 2018), the care team implemented a weekly questionnaire based on their own experience with lung cancer care. As time passed, they decided to adapt the questionnaire and to use an internationally validated instrument. Based on a literature search, the PRO-CTCAE, a library that represents 78 symptomatic toxicities for weekly symptom monitoring of patients with cancer was selected. The reasons for this choice were: international use, validation per item performed, and scientific evidence for improvement (Basch et al., 2016; Denis et al., 2019).

The adapted weekly questionnaire was developed by the authors of the manuscript, three of which are working at the hospital and was implemented in February 2019. The selection of the items of the PRO-CTCAE was based on a literature search on the most common or threatening events for lung cancer (Mok et al., 2009; Reck et al., 2016; Soria et al., 2018). The selected items were: mouth/throat, nausea, vomiting, constipation, diarrhea, shortness of breath, cough, rash, general pain, fatigue, anxiety, discouraged state, and sadness.

As patients suffer from psychological, spiritual, palliative, social, family-related and financial needs (Maguire et al., 2012; Temel et al., 2010; Ugalde et al., 2012), the care team decided to add some extra questions on these topics. The list of all questions and alerts generated is integrated in the supplementary information.

ICHOM LUNG CANCER OUTCOME SETS

The care team also collected the ICHOM outcome data for lung cancer. The PROMs in the ICHOM standard set for lung cancer (ICHOM, 2017) are tracked by EORTC QLQ-C30 and its lung cancer-specific module EORTC QLQ-LC13. The EORTC questionnaires are collected by other hospitals in Belgium as well as abroad. The goal of the care team was to benchmark these results with other hospitals.

Follow-up of PROMs

A follow-up was put in place for the weekly questionnaire. The digital platform generates alerts by e-mail to the appropriate caregivers based on the responses of the patient. For every item, a threshold was defined to trigger an alert to the care team (see supplementary information). Along with the alerts, the care team has a visual overview of the weekly responses in the digital platform. Alerts are discussed on the weekly multidisciplinary team meetings and patients are contacted by phone or visited at the day care center during their visit by the appropriate care giver to follow up on the alerts. Also, the oncology nurse discusses the responses on the weekly questions with patients at every visit to the day hospital.

In Belgium, there is an e-health hub in place for the electronic exchange of messages between care givers (https://www.cozo.be/ehealth). The GPs receive the alerts of their patients within this e-health messaging system, next to all other messages of their patients, like blood results. These alert messages also include which therapy the patient receives and the possible side effects.

Results

Patient characteristics

Table 1 provides an overview of the patient characteristics of the patients included in the two arms of the pilot and of the other patients included in the digital platform. In all subgroups, the majority of patients are male (total = 79%) and the average age is around 70 years. Most patients have a high school diploma (total = 56%). Almost all patients have a WHO performance score of 0 (Able to carry out all normal activity without

restrictions) or 1 (Restricted in physically strenuous activity but ambulatory and able to carry out light work). Most patients in all subgroups are diagnosed with a non-small-cell lung carcinoma (total = 77%). At the start of the disease, most patients were diagnosed with Stage IV disease at outset or diagnosed with de novo metastatic disease (total = 50%). The majority were treated with chemotherapy or a combination of chemotherapy and immunotherapy.

Table 1: Patient characteristics of included patients in the platform during the period January 2018–September 2020

	Pilot		Patients included in the platform, excl. pilot n=171 (%)	Total n=201 (%)
	Weekly questionnaire n=15 (%)	No weekly questionnaire n=15 (%)		
Gender				
Male	10 (67%)	13 (87%)	135 (79%)	158 (79%)
Female	5 (33%)	2 (13%)	36 (21%)	43 (21%)
Age				
Average (range)	67 (34-86)	70 (54-84)	69 (38-90)	69 (34–90)
30–39	1 (7%)	0 (0%)	1 (1%)	2 (1%)
40–49	0 (0%)	0 (0%)	7 (4%)	7 (3%)
50–59	2 (13%)	2 (13%)	21 (12%)	25 (12%)
60–69	5 (33%)	5 (33%)	60 (35%)	70 (35%)
70–79	5 (33%)	7 (47%)	59 (35%)	71 (35%)
80–90	2 (13%)	1 (7%)	23 (13%)	26 (13%)
Diploma				
Primary school	3 (20%)	3 (20%)	42 (25%)	48 (24%)
High school	10 (67%)	7 (47%)	96 (56%)	113 (56%)
Bachelor or higher	2 (13%)	1 (7%)	28 (16%)	31 (15%)
Unknown	0 (0%)	4 (27%)	5 (3%)	9 (4%)
WHO score (1)				
0	3 (20%)	2 (13%)	8 (5%)	13 (6%)
1	12 (80%)	13 (87%)	151 (88%)	176 (88%)
2	0 (0%)	0 (0%)	6 (4%)	6 (3%)
3	0 (0%)	0 (0%)	1 (1%)	1 (0%)
4	0 (0%)	0 (0%)	2 (1%)	2 (1%)
Unknown	0 (0%)	0 (0%)	3 (2%)	3 (1%)
Type of cancer (2)				
NSCLC	12 (80%)	9 (60%)	134 (78%)	155 (77%)
SCLC	3 (20%)	5 (33%)	32 (19%)	40 (20%)
Other	0 (0%)	1 (7%)	5 (3%)	6 (3%)
Stage of the disease at the start of the treatment (not the current stage)				
Stage I	3 (20%)	1 (7%)	9 (5%)	13 (6%)
Stage II	0 (0%)	1 (7%)	17 (10%)	18 (9%)
Stage III	2 (13%)	2 (13%)	59 (35%)	63 (31%)
Stage IV	10 (67%)	11 (73%)	80 (47%)	100 (50%)
Unknown	0 (0%)	0 (0%)	6 (4%)	7 (3%)
Type of systemic therapy received				
Chemotherapy	0 (0%)	8 (53%)	63 (37%)	71 (35%)
Immunotherapy	1 (7%)	0 (0%)	17 (10%)	18 (9%)
Chemo-immunotherapy	12 (80%)	5 (33%)	79 (46%)	96 (48%)
TKI	1 (7%)	0 (0%)	5 (3%)	6 (3%)
Combination of treatments (Chemo/Immuno/TKI)	1 (7%)	2 (13%)	7 (4%)	10 (5%)

(1) WHO- performance score: 0 – Able to carry out all normal activity without restrictions.; 1 – Restricted in physically strenuous activity but ambulatory and able to carry out light work.; 2 – Ambulatory and capable of all self–care but unable to carry out any work; up and more than 50% of waking hours.; 3 – Capable of only limited self-care; confined to bed or chair more than 50% of waking hours.; 4 – Completely disabled; cannot carry on any self-care; totally confined to bed or chair.

(2) NSCLC = non-small-cell lung carcinoma; SCLC = Small-cell lung carcinoma

Table 2: Analysis of response rates and retention of included patients in the platform during the period January 2018–September 2020

Feasibility	Administrative data (all patients, excluding pilot arm without weekly questionnaires), period January 2018–September 2020, n=186
Response on weekly questionnaires	
Weekly questionnaires sent (in total)	3,028
Weekly questionnaires responded (in total)	2,835
Percentage of questionnaires responded	92%
Response rates per patient: % of questionnaires responded per patient	
100% of questionnaires responded, n (%)	66 (35%)
90–99% of questionnaires responded, n (%)	44 (24%)
80–89% of questionnaires responded, n (%)	28 (15%)
70–79% of questionnaires responded, n (%)	13 (7%)
60–69% of questionnaires responded, n (%)	12 (6%)
50–59% of questionnaires responded, n (%)	9 (5%)
<50%, n (%)	3 (2%)
0%, n (%)	11 (6%)
Total, n (%)	186 (100%)
Average response rate/patient (%)	83%
Retention: average response rate per number of questionnaires sent/patient, in %:	
1 questionnaire sent (n = 10, 5% of patients)	30%
2–4 questionnaires sent (n = 42, 23% of patients)	70%
5–9 questionnaires sent (n = 41, 22% of patients)	88%
10–24 questionnaires sent (n = 53, 28% of patients)	90%
25–50 questionnaires sent (n = 29, 16% of patients)	92%
50–100 questionnaires sent (n = 11, 6% of patients)	98%
Response rates on EORTC questionnaires	
EORTC questionnaires sent (in total)	932
EORTC questionnaires responded (in total)	835
Percentage of questionnaires responded	90%
Average response rate / patient	88%

Evaluation of outcomes

For the evaluation, we used the Framework for Implementation Outcomes (Proctor et al., 2011) composed of eight types of Implementation Outcomes: feasibility, acceptability, adoption, appropriateness, fidelity, implementation cost, penetration, and sustainability. The feasibility was evaluated through (1) data analysis of all included patients in the digital platform for the period January 2018–September 2020, (2) a pilot study on the feasibility and (3) semi-structured interviews with the care team. The other implementation outcomes were evaluated through the interviews with the care team.

1. Feasibility

We examined whether it is feasible for patients to participate in the weekly digital follow-up. Overall, 95% of all lung cancer patients of the two participating thoracic oncologists agreed to participate in the digital follow-up during the period January 2018–September 2020 (201 participating patients). For the analysis of the response rates (see Table 2), patients in the pilot arm without weekly questionnaire (n=15) were excluded. In total, for 186 patients, 3,028 weekly questionnaires were sent. 92% of these weekly questionnaires were responded by patients. These response rates are high for patients included during a long period in the digital platform (>90%). The response rates are lower for patients when

only a few questionnaires were sent. Patients with fewer than five questionnaires sent (n=52) were evaluated to explain the low response rates of these patients. In this group, 28 patients had response rates lower than 75%. Reasons for the lower response rates were decease of patient shortly after the start of the digital pathway (n=16), pause of the treatment (n=3) and recent start of the care pathway (n=3). For the 7 other patients the reason was unclear, 3 of them unsubscribed to the questionnaires. The response rates on the EORTC questionnaires are also high: 88% of the EORTC questionnaires are responded by patients. We investigated whether the patient characteristics (gender, age, diploma, WHO score, type of cancer, stage and treatment) were correlated with the response rates. None of them had a significant correlation ($p>0.05$).

In the pilot study, patients filled in a validation questionnaire. Ten out of 15 patients filled in the questionnaire at the beginning of the study period and five at the end. Four patients passed away during the study period, which explains the lower response rate at the end of the study period. The majority (90%) of patients felt that this online system is easy to use. Most patients did not need support to answer the questions. In the validation questionnaire, two out of 10 patients stated that they needed help (see Table 3). The overall response rates of these two patients in the pilot study were 67% and 77%, which is lower than the overall average response rate of 83% (see Table 2). According to patients in the pilot study, the questions were relevant (70%) or moderately relevant (30%), and the questions were clear (90 %) and not difficult (80%).

Table 3: Results from the patient validation questionnaire

Question	At the beginning of the study period (n=10)		At the end of the study period (n=5)	
	N	%	N	%
How was your experience with the online system?				
Very difficult/difficult	0	0%	0	0%
Moderate difficult	1	10%	0	0%
Easy/very easy	9	90%	5	100%
Did you need help with filling in the questionnaire?				
Yes	2	20%	0	0%
Did you receive the help you need? (n=2): yes				
From whom? (n=2): friends and family	8	80%	5	100%
No				
How relevant did you find the questions?				
Totally not relevant/not relevant	0	0%	0	0%
Moderate relevant	3	30%	2	40%
Highly relevant/relevant	7	70%	3	60%
How clear did you find the questions?				
Very unclear/unclear	0	0%	0	0%
Moderately clear	1	10%	1	20%
Very clear/clear	9	90%	4	80%
How difficult did you find the questions?				
Very difficult/difficult	1	10%	0	0%
Moderately difficult	1	10%	0	0%
Not difficult at all/not difficult	8	80%	5	100%
Did you have other symptoms you wanted to report?				
Yes	3	30%	0	0%
Which symptoms? Arthralgia and myalgia (n=1), varying defecation (n=1), dry mouth (n=1)	7	70%	5	100%
No				

These findings were confirmed in the interviews with the care team. A small proportion of patients do not have the digital skills to fill in the questionnaires themselves. In this situation, a family member usually fills in the questionnaire. The oncology nurse estimates that in 15% of the cases a family member (partner/child) fills in the questionnaire. Those patients are often older (80+) and/or do not have access to the internet.

2. Appropriateness

We also evaluated the appropriateness of the digital health solution. In the interviews the multidisciplinary lung cancer care team stated that the defined standard care pathways are clear for the care team and that it makes planning of care activities easier. One improvement suggestion mentioned by the palliative support is that this support is not included in the standard sequencing of activities. Therefore, palliative support is often brought up only at a late stage of the disease. This could be improved by entering a standard moment in every care pathway where the care team needs to evaluate whether palliative support can be offered to patients. Furthermore, the caregivers mentioned that for some patients, the question on end of life and palliative concerns are confronting. Based on this feedback, the formulation of this question will be adapted.

3. Acceptability

All of the interviewed caregivers stated that the PROMs facilitated the communication between the patient and the caregiver. In particular, the interviewed psychologist and palliative nurse declared that alerts are an important trigger to start a conversation on psychological and palliative support. In the pilot study, seven patients in the intervention arm with a weekly digital questionnaire had contact with the psychologist; four of them had more than one contact. In the standard care arm, only two patients had contact with the psychologist. This is an interesting finding and warrants further research with a larger sample. For palliative support, we could not see any difference between the standard care and the intervention arm in the pilot study.

4. Adoption

Most patients respond positively to the digital care pathway. Throughout the entire period (January 2018–August 2020), 95% of targeted patients are included in the digital platform and only 3 patients unsubscribed to the questionnaires.

5. Fidelity

During the implementation, some small adaptations were made to the questionnaire. A question was added so that patients could indicate if they did not want to be contacted by the care team. Also, an extra open field was added for patients to add remarks or other adverse events.

6. Implementation cost

Unfortunately, the lung cancer care team did not register the time spent for the implementation of VBHC with weekly follow-up. In the interviews, the care team members declared that they gained efficiency by the digital follow-up: consultations and visits can proceed in a more efficient and focused manner. Also, there was no expansion of the team because of the digital follow-up.

7. Penetration

Since 2021, the digital platform has also been implemented in the other campuses of the hospital for lung cancer patients. Also, the surgery care pathway for lung cancer patients was implemented. In addition, the digital platform was also implemented for other pathologies in the hospital, namely COPD, breast cancer, IBD and prostate cancer.

8. Sustainability

The thoracic oncologists were the driving forces behind the installation of the multidisciplinary care team, standard care pathways, and the implementation of the digital platform. In the interviews, this was appointed as a key success factor in the implementation process. The engagement of all members of the care team, especially the oncology nurse, from the start of the development process was also essential for successful implementation.

As a large part of the study was conducted in 2020, the COVID-19 pandemic had an impact on the digital follow-up. During the first COVID wave (March-April 2020), there was a high workload in the nursing department. As a result, the oncology nurse responsible for the digital follow-up was scheduled on a hospital ward. For this reason, alerts were not followed up properly and patients felt left on their own. In May 2020, the hospital decided to relieve all oncology nurses from extra duties and the follow-up could be reinstated.

Discussion

The aim of this study was to evaluate the implementation of VBHC principles for lung cancer patients with the weekly follow-up of PROMs. Our results provide several important lessons.

First, the digital health solution needs to be integrated into healthcare team practices, and responses should be appropriately managed, as was also recommended by Aapro et al. (2020). In our case study, the care team evaluates the alerts during weekly team meetings and the appropriate members of the care team take relevant actions. Also, the thoracic oncologists use the PROMs during consultations and the oncology nurse discusses the responses at every visit to the day hospital. This cycle of continuous feedback between patients and their care teams, guided by the digital PROMs, seems to be crucial for successful implementation. In contrast to existing literature, the response rates in our study remain high (>90%) for the entire care process and we found no significant difference between patient characteristics (gender, age, diploma, WHO score, type of cancer, stage, and treatment) (Berry et al., 2015; Børøsund et al., 2013; Cavanna et al., 2020). Also, digital healthcare increased rapidly due to COVID-19 (Seixas et al., 2021). In our case study, as the system was already implemented before the COVID-19 pandemic, the follow-up during the pandemic could be continued more easily in a digital way. The teleconsultations, introduced as a consequence of the COVID-19 pandemic, were structured around the responses on the digital platform.

Second, it is important that a multidisciplinary care team is put in place to respond to patients' clinical, psychological, palliative, financial, and family-related concerns. Our case study involved not only thoracic oncologists and nurses, but also a psychologist, a palliative care nurse, a nutrition specialist, and social services. This leads to a more holistic approach of patient care, rather than just focusing on the pure medical problems. We saw that the possibility to digitally report psychological problems, end-of-life discussions, and palliative needs led to a higher uptake of these issues. Also, Porter and Lee (2013) viewed this multidisciplinary team as an essential step in implementing VBHC. Furthermore, Prades et al. (2015) concluded that multidisciplinary team meetings (MDTs) resulted in better clinical and process outcomes for cancer patients, with evidence of improved survival, also for lung cancer patients.

Third, leadership is an important enabler in the implementation process (Cossio-Gil et al., 2021). In our study, the thoracic oncologists were the driving forces of the implementation. They convinced both the multidisciplinary care team and the patients of the potential benefits, by taking small steps and allowing time and space for adaptation and feedback. Support by the management of the hospital was also an important enabler.

Fourth, we recommend using a digital tool, rather than reporting PROMs on paper. Such a tool should enable (1) the collection of PROMs and clinical outcomes, (2) the visualization of these data using dashboards, and (3) the provision of feedback to clinical teams and patients, as also recommended by Aapro, Bossi et al. (2020) and Cossio-Gil, Omara et al. (2021). Moreover, the digitally reported data can be used for further research, quality evaluation of the care process, and improvement cycles.

Our findings are limited by the fact that the study was a single-center study. Also, we have no information about whether the patient or a family member responded to the questionnaire. This meant we could not investigate the influence of questionnaires completed by an informal caregiver versus patient completed questionnaires. Also, we did not collect information on the time spent on the implementation. As a result, we were not able to evaluate the implementation costs, which is an outcome measure in the Framework for Implementation Outcomes (Proctor et al., 2011). Another limitation is the small number of patients with small-cell lung cancer, which is often a rapidly progressive disease, and patients on targeted therapies who may have stable disease with limited symptoms.

We did not investigate the clinical implications and the responses to the questionnaires. This topic requires attention in further research. Also, we did not investigate the extent to which the GPs use the results and the impact of their level of experience with lung cancer and engagement, so this would be interesting for further research.

Conclusion

This study has shown that it is feasible to implement a weekly digital follow-up of PROMs in routine clinical practice for lung cancer patients. The digital platform is user-friendly, questions are clear, and the follow-up of PROMs is integrated in the multidisciplinary care delivery. As a result, the response rates are high, and the weekly follow-up had a positive impact on the patient–provider communication and makes it easier to discuss psychological and palliative care needs.

Supplementary information - chapter 1

Supplementary information – Table A: List of PRO-CTCAE adverse events included in the weekly questionnaire and alerts generated to the care team

SYMPTOM ITEM	Alert trigger via mail	To whom?
Mouth/throat sores	Average score > 1 on attributes*	
Nausea	Average score > 1 on attributes*	
Vomiting	Average score > 1 on attributes*	
Constipation	Average score > 1 on attributes*	Dedicated oncology nurse
Diarrhea	Average score > 1 on attributes*	Treating Thoracic oncologist
Shortness of breath	Average score > 1 on attributes*	
Cough	Average score > 1 on attributes*	Dietician: Only alert generated for nausea, vomiting
Rash	Answer = yes	
General pain	Average score > 1 on attributes*	
Fatigue	Average score > 1 on attributes*	
Anxiety	Average score > 1 on attributes*	Dedicated oncology nurse
Feeling discouraged	Average score > 2 on attributes*	Treating thoracic oncologist
Sadness	Average score > 2 on attributes*	Psychologist

* Scores on attributes: 5-point Likert scale; 0 (lowest score) – 4 (highest score)

Source: PRO-CTCAE (2020)

Supplementary information – Table B: Added questions next to the PRO-CTCAE adverse events and alerts generated to the care team

ITEM	Alert trigger	To whom?
In the beginning of the questionnaire:		
Weight	Decline by 2.5% vs take-off weight	Dedicated oncology nurse
Fever	Answer = yes	Treating thoracic oncologist Dietician
After the PRO-CTCAE events:		
Are you concerned about financial and/or practical matters (such as the cost of treatment, the need for home help, the right to premiums, etc.)?	No alert on the first question	
If answer = yes: Our social service can help you with questions about financial and/or practical matters. Would you like to have a meeting with the social services at your next hospital appointment?	Alert when answer = yes	Dedicated oncology nurse Treating thoracic oncologist Dietician + Social service
Do you have questions about the meaning of life and meaning of what happens to you? Do you need a pastoral visit or a conversation that fits your philosophy?	Alert when answer = yes	Dedicated oncology nurse Treating thoracic oncologist Dietician + Pastoral support
Do you have questions or concerns about the end of life, palliative concerns, etc.?	No alert on the first question	
If answer = yes: The palliative nurse can help you with your questions about this. Would you like a meeting with the palliative nurses at your next appointment?	Alert when answer = yes	Dedicated oncology nurse Treating thoracic oncologist Dietician + Palliative nurse
Are you concerned about your partner and/or family?	No alert on the first question	
If answer = yes: Would you like to have a conversation with the social services or the psychologist about this at your next hospital appointment?	Alert when answer = yes	Dedicated oncology nurse Treating thoracic oncologist Dietician + Social service, psychologist
The care team will contact you if you have any complaints. If you do not want this, please indicate this.	If the patient indicates the button	Dedicated oncology nurse Treating thoracic oncologist Dietician + other caregiver receiving the alert

Source: Developed by the Lung Cancer Care Team.

Supplementary information – Questionnaires semi-structured interviews

Questionnaire semi-structured interviews of the care team

The semi-structured interviews were structured according to the characteristics of a care pathway. Vanhaecht (2007) defined the characteristics of a care pathway as follows: (1) the goals and key elements of care are based on evidence, best practice, patients' expectations and their characteristics; (2) the communication is facilitated among the team members and with patients and families; (3) the care process is coordinated: the roles and the sequencing of the activities of the multidisciplinary care team, the patients and their relatives are clear; (4) the outcomes are evaluated and monitored; and (5) the appropriate resources are identified.
We also included some questions about the process, some general questions, and questions about the follow-up in primary care.

Questionnaire:

Clear goals:
- Are clear goals agreed with the patient based on his expectations, evidence, and best practices?
- To what extent are the patient's expectations taken into account in care delivery?
- Are these goals made explicit in the Electronic Health Record? Is it clear to each caregiver in the team what the objectives are?

Communication
- How is communication with the patient organized?
- How is communication as a team organized?
- To what extent does the digital pathway improve communication with the patient?
- Does the digital pathway improve communication as a team?
- What are the points of attention?

Coordination
- Does the digital care pathway help to improve the coordination between the different activities?

Outcomes
- Digital monitoring of outcomes:
    - Is it feasible for patients to fill out the questionnaire digitally?
    - How do you get patient alerts sent (mail/report Awell/other)? What issues do you get to see?
    - Do you always get a report or only if certain thresholds are exceeded?
    - Who gets what alerts?
    - Do the alerts have to be handled in the digital system?
    - Who follows up on the alert?
    - Is it useful? What are the advantages of monitoring outcomes digitally? What are the disadvantages?
- PRO CTC AE – content validity:
    - Are there things that are still missing in the weekly questionnaire? (Symptoms/other?)
    - Do patients experience the questions as difficult?
    - How do patients experience the online system?
    - Are the questions clear?

Follow-up
- How are the results followed up by you?
- How are the results discussed in team meetings?
- How is the follow-up process organized in case of non-response of the patient?

Resources

- Is the team increased because of the digital follow-up? Are you able to follow up on all alerts?

Process

- To what extent has the process changed because of the digital follow-up?
- What was first? The multidisciplinary team and follow-up? Or has the digital care pathway also caused changes in the organization of care?

General

- What lessons are learned about the implementation?
- Does it make the work easier?
- Do you feel you are delivering better quality?
- Did you already get feedback from patients about the system?

Additional questions:

How is the follow-up done in primary care?
How many primary care physicians do this?
Impact of the COVID-19 pandemic on the organization of care?

<u>Questionnaires semi-structured interviews of patients</u>

The interview started with an introduction of the interviewer and an explanation of the purpose of interview. Subsequently, some questions were asked:

- How long have you been in treatment for lung cancer?
- What is your general experience with the care delivered in AZ Delta? What are you very satisfied with? What could be improved?
- How long have you been in the digital care pathway?
- What is your experience with the online system?
- Is it feasible to fill out the questionnaires weekly?
- Did you need help filling in the questionnaire?
- How relevant did you find the questions?
- How clear did you find the questions?
- How difficult did you find the questions?
- Did you have other symptoms you wanted to report?

Chapter 2: Benchmark of processes and costs of care of six Belgian hospitals

Introduction

The concept of VBHC strives to maximize the value provided to patients by improving the outcomes that matter most to them in proportion to the costs incurred to achieve those outcomes. An important component of VBHC is to measure outcomes and costs of care pathways. Subsequently, this information should be used to improve the 'value' for patients, where value is defined as the outcomes achieved relative to the costs. Benchmarking of outcome and costs is seen as a main component in the implementation of VBHC (Cossio-Gil et al., 2021; EIT Health, 2020).

According to Porter and Lee (2013), few clinicians have any knowledge on the costs of the full cycle of care delivered. Also in Belgium, most hospitals have little information on the costs of care for each medical condition. However, in other European countries, cost calculation of hospital care is a key component of hospital management (Špacírová et al., 2022).

Therefore, this research focusses on the cost component in VBHC, more specifically on hospital costs as this is an important source of healthcare expenditures. In the 34 OECD countries, hospitals were on average responsible for 39% of healthcare expenditures by primary providers of healthcare. Other primary providers are: residential long term care facilities (8%), ambulatory providers (26%), retailers (16%) and providers of preventive care and others (12%).(OECD, 2023b)

The aim of this research is to explore the feasibility of setting up a benchmark on the process and cost data of Belgian hospitals. Four research questions have been formulated: (1) How can we measure costs? (2) Is it feasible to compare costs on a pathology level in a benchmark with multiple hospitals? (3) Which assumptions and attention points should be taken into account? (4) What are the learnings from the benchmark?

In a first pilot, six hospitals agreed to participate in this benchmark with data of 2019.

Material and methods

The methods are elaborated based on the checklist for methodology of top-down costing studies, described by Špacírová et al. (2020).

Study characteristics

The purpose of this study is to calculate the resource use and costs of care on a patient and pathology level within a hospital and compared to other hospitals. The cost study focusses on hospital costs and will be set up from a providers' perspective. It is a multicenter study, and the sample is composed of all patients hospitalized in six Belgian hospitals situated in Flanders in 2019. This sample of hospitals consists of two large hospitals (revenue in 2019 > € 250 million), two medium-sized hospitals (revenue in 2019 between €100 and €250 million) and two small hospitals (revenue in 2019 < €100 million).

Level of detail in costing

In this study, we conduct a full costing analysis, which means that all hospital costs will be allocated to a patient visit. The costs will be aggregated based on the patient's diagnosis and illness severity, based on the APR-DRG classification used in Belgium. This system groups hospital cases based on their clinical characteristics and expected resource utilization. In Belgium, every hospitalization and day care visit is assigned a DRG and SOI through a grouper program that takes into account the patient's diagnoses, procedures, and demographic factors (Van de Voorde et al., 2013). According to an international comparison, most European countries use DRGs as the cost object for hospital cost calculation (Busse et al., 2013; Špacírová et al., 2022; Van de Voorde et al., 2013).

In cost calculation in healthcare, a distinction is usually made between micro-costing and gross-costing, based on the level of detail to collect resource information. In micro-costing, all relevant hospital services are identified at the most detailed level, while in gross costing, costs are identified at a highly aggregated level, often based on inpatient days only. Another distinction is often made between top-down and bottom-up costing. Top-down costing starts generally from the organizations' accounting information and all costs are allocated to a patient level by allocation keys, while in bottom-up costing, costs are calculated for every individual patient by detailed measurements. When using bottom-up costing, it is important to note that certain resources, like laundry and nursing department management, cannot always be attributed to a single patient. These types of resources should be allocated to a patient using top-down methods. Additionally, bottom-up exercises are often based on a sample of patients, so the accuracy of the results depends on the size of the sample. (Špacírová et al., 2020)

Top-down micro-costing is frequently used in healthcare. According to a comparison of nine European countries (Špacírová et al., 2022), eight of those countries - England, France, Germany, Italy, Portugal, Slovenia, Spain, and Sweden – use (at least partly) top-down micro-costing for cost calculation. Also in our research, we decided to use top-down micro-costing. We see some advantages in using this methodology: (1) all hospital costs are allocated to a cost object (full costing), (2) available information can be used (no manual registrations) and (3) the calculation is automatable and reproduceable without extra measurements.

Data collection

This study aims to establish a reproducible and automatable method for calculating costs in order to enable benchmarking between more hospitals in the future. To achieve this goal, the available accounting and activity information from hospital information systems was used for the year 2019. The hospitals received a detailed overview of the necessary data sources and the required fields per source (see supplementary information chapter 2 – table A).

An important data source of this costing study is the accounting information of the participating hospitals. Belgian hospitals are obliged to follow the rules laid down in the Royal Decree of August 14, 1987, determining the minimum classification of the general chart of accounts for hospitals and in the Royal Decree of June 19, 2007, on the annual accounts of hospitals. All costs are registered on legally defined cost categories and cost centers. The detailed accounting information per cost center and general ledger account was collected in each hospital. (Finhosta, 2022; Koninklijk Besluit, 1987, 2007)

Belgian hospitals also dispose of detailed activity information on a patient and visit level through standardized data sources. One crucial data source is the claims data (nomenclature), which is highly detailed and encompasses 28,000 different activities registered at the patient and visit level. The claims data was standardized in consultation with the nomenclature experts of the participating hospitals and an activity name was added to each nomenclature number based on the description e.g. emergency visit, type of surgery, RX, CT, …. Additionally, data from various other sources was collected, including OR data on the duration of the surgery per patient, pharmacy data on implants and pharmaceuticals per patient visit, central sterilization data on the number of sterilized sets per patient visit, and care registration data (Minimal Hospital Data, Belgian Nursing Minimum Data Set) on DRG and SOI per stay and care intensity per pathology.

To ensure compliance with the General Data Protection Regulation (GDPR), which requires contractual agreements between healthcare facilities as data controllers and external processors, a data protection supplier agreement addendum was created and signed with each participating hospital. (Zorgnet Icuro, 2018)

The data was stored in a Microsoft SharePoint Online environment located in EU data centers, and access to the data was granted via multi-factor authentication and linked to a specific folder or project. The data was encrypted both in transit and at the client and server sites for full encryption.

To set up the benchmark, one person in each hospital was responsible for data delivery and was appointed as the central contact person. In each hospital a project group was formed consisting of financial staff (controller and/or CFO) and data experts. The project group was responsible for data delivery and validating the methodology and the results.

To address the second and third research questions, namely the assumptions and critical success factors and the learnings from the benchmark, interviews were conducted with one or two individuals from each of the six participating hospitals during the period January-February 2023. In total, nine respondents were interviewed. The interviews lasted for 1 hour. A questionnaire, provided in the supplementary information of chapter 2, was used for the interviews.

Table 7: List of interviewees per hospital, hospital number, function and date of the interview

Interviewee	Hospital	Function	Date of interview
1	Hospital 1	Data manager	25/1/2023
2	Hospital 1	Financial controller	25/1/2023
3	Hospital 2	Chief Financial Officer	26/1/2023
4	Hospital 2	Financial controller	26/1/2023
5	Hospital 3	Financial staff	31/1/2023
6	Hospital 4	Data manager	31/1/2023
7	Hospital 5	Financial staff	31/1/2023
8	Hospital 5	Data manager	31/1/2023
9	Hospital 6	Director processes and quality	9/2/2023

Method for cost calculation

The cost calculation process is accomplished through seven steps, as outlined in Figure 3. In this section, these steps are explained.

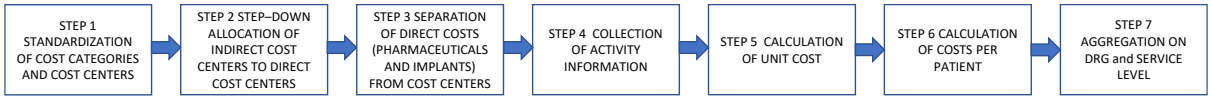


Figure 3: Step by step composition of a top-down micro-costing model

Step 1: Standardization of cost categories and cost centers

In this first step, the costs were grouped into cost categories based on the legal general ledger accounts. A distinction was made between: (1) staff costs, (2) equipment, (3) materials, (4) pharmaceuticals and implants, (5) doctors' costs, (6) other operating costs, (7) financial costs and (8) extraordinary costs. These categories were further divided into subcategories. Also, the cost centers were grouped on different levels. For example, the cost centers for nursing units were grouped into categories based on the type of patient hospitalized in each ward (e.g. surgical, pediatric, etc.) and the cost center radiology was divided into subcategories such as NMR, CT, echo and scan based on cost information or claims data. Figure 4 gives an overview of the cost categories, the cost category groups and the different levels of cost center groups.

To ensure comparability between hospitals, the cost information recorded in each cost center was standardized. This is necessary as there may be differences in the practical implementation of the legal accounting rules. To standardize the cost categories and cost centers, discussions were performed with each participating hospital to understand their cost recording processes. Based on these discussions, the accounting data from each hospital were adjusted to ensure comparability.

The following adjustments were made:

- Some of the hospitals classify nurses working in a mobile crew under the department they worked for, and others do so under a general cost center. Extra information was requested from the hospitals that record the costs of the mobile crew on a general cost center to allocate these costs to the correct department where the work was performed.

- One hospital has a specific machine (a PET CT scan) that is used by multiple hospitals. Only the costs related to the activities for their own hospital are taken into account for the cost calculation.
- There was a difference between hospitals on how doctors' costs are registered. Therefore, specific doctors' cost centers were created, and all doctors' costs registered on nursing departments were moved to these cost centers.
- Expenditures that lack a direct association with the clinical activities of the hospital, such as those related to on-site commercial facilities (e.g., hallway shops, cafeteria, hairdresser), visitor parking, … were excluded.

The hospitals received a comprehensive overview of modifications made to their cost structure, including cost exclusions and reallocations between cost centers.

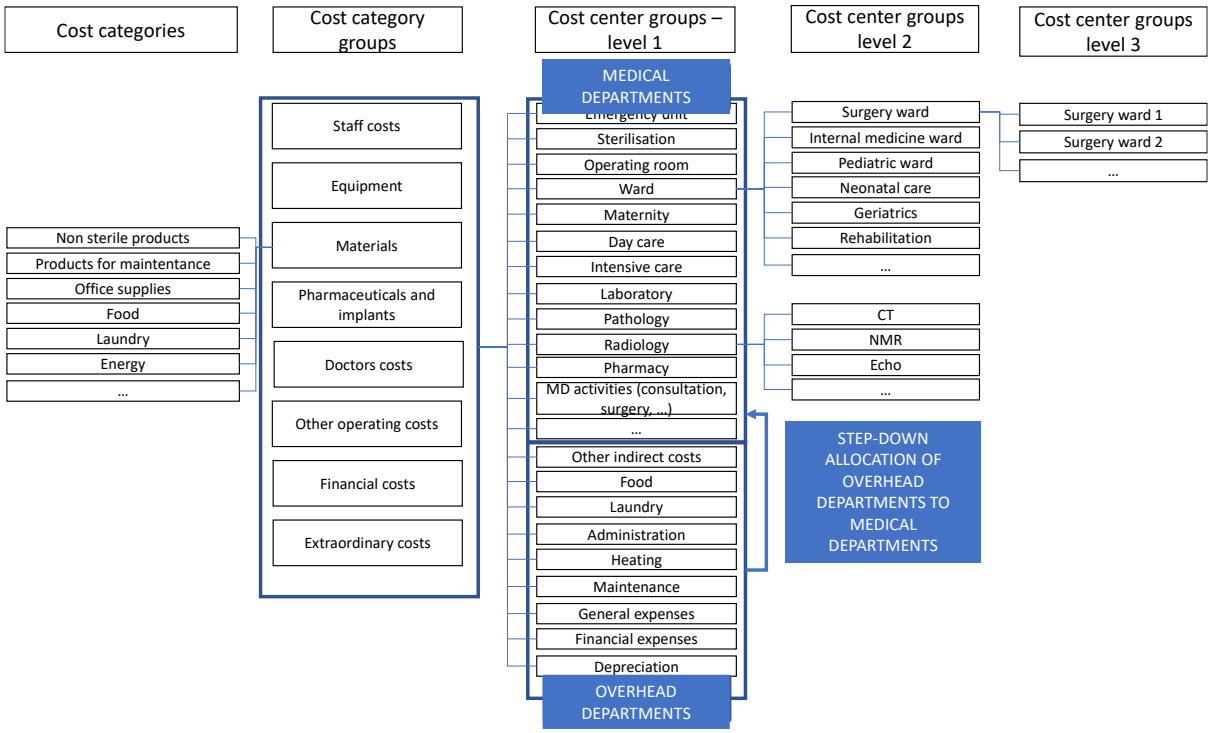


Figure 4: Visualization of step 1 'Standardization of cost categories and cost centers and step 2 'Step-down allocation of the costs of the overhead departments to the medical departments'

Step 2: Step-down allocation of the costs of the overhead departments to the medical departments

In hospital cost accounting, cost centers are categorized as overhead departments or medical departments. Overhead departments, like administration, heating, and maintenance, do not directly contribute to patient care, whereas medical departments, such as nursing departments, OR, and radiology, are directly involved in patient care.

In literature, three methods are described for allocating overhead costs to medical cost centers. The first method is the direct allocation of overhead costs to medical departments without interaction between overhead departments. A second method is the 'step-down allocation' method. This method assigns overhead costs stepwise to medical departments and to the remaining overhead departments. As a result, interactions between

departments are partially taken into account. A third method for allocating overhead costs is the reciprocal method, in which overhead costs are assigned to both medical departments and all other overhead departments. This procedure is undertaken several times to eliminate all unallocated amounts. (Busse et al., 2013; Drummond et al., 2015)

Belgian hospitals are obliged to allocate the costs of the overhead departments recorded on temporary cost centers (like laundry, administration costs, energy, …) to medical departments using the legally defined step-down allocation method. This method assigns the costs of the overhead departments in stages to medical departments and to the remaining overhead departments using legally defined allocation keys, such as the square footage of each medical department for heating, FTE for administration, and patient days for food (see supplementary information chapter 2 - Table B). As all hospitals are obliged to use these keys, this method was used to allocate the costs of the overhead departments to the medical departments.

Step 3: Direct costs

The direct allocation of costs to individual patients is the most accurate method of cost allocation. However, in Belgian hospitals, only the costs of pharmaceuticals and implants are recorded at the patient level. For pharmaceuticals, a detailed registration is available based on ATC codes (the Anatomical Therapeutic Chemical classification system). This classification system allows for the identification of the specific therapies, drugs, or other substances that were administered to each patient during their hospitalization (WHO, 2022).

To allocate these costs directly to patients, detailed records of medications and implants and their costs were extracted at the patient level from the pharmacy software package. Following, these costs were separated from the pharmacy cost center and assigned directly to patients.

Step 4: Collection of activity information

In the fourth step of the study, detailed activity data on a patient level was obtained from each hospital (see section on data collection). Several quality control procedures were carried out on the collected activity data. Firstly, any data that lacked a visit ID or DRG was excluded. Secondly, the duration of the patient's surgery in the OR data was evaluated. Long durations (exceeding 12 hours) and negative durations were substituted with the specialty's average duration of a surgery. The hospitals received an overview of the data quality and the excluded data.

Step 5: Calculation of unit costs

In step five, the calculation of a unit cost for each activity was carried out. The literature describes various methods for calculating unit costs, including weighting statistics, relative value units, and marginal mark-up percentages (Busse et al., 2013; Finkler et al., 2007; Tan et al., 2009).

The weighting statistics method involves using service time as a proxy for resource consumption, such as cost per treatment minute or patient day. This method is frequently used in services like physical therapy and the OR, where the costs are divided by the

number of minutes of procedures performed to determine a cost per minute. The logic behind this approach is that longer procedures consume more resources.

The relative value units method requires conducting a study on a specific cost center to determine the relative costliness of each type of service performed. This method is often utilized in medical-technical departments such as laboratories and radiology. In this approach, a base value is assigned to one type of procedure, and all other procedures are assigned a relative value based on their costliness. If for example one procedure receives a value of 1, then another procedure that takes twice as much time and costs receives a value of 2.

The marginal mark-up percentages method requires adding a percentage to the direct costs, calculated by dividing the annual indirect costs by the annual direct costs per department. This method is commonly used in the pharmacy and medical supplies cost center. If the pharmacy department spends €100.000 on direct costs for pharmaceuticals and €10.000 on other costs, then the mark-up percentage is 10%. As a result, the cost of the drug will be calculated as the direct cost + 10%.

To determine the method for calculating unit costs for each activity, representatives from each medical department and the financial department in two hospitals were interviewed. Based on these interviews, allocation keys that are feasible to collect in each hospital were defined, with the understanding that further refinement in the future may be necessary. The unit costs are calculated using weighting statistics or relative value units. The unit cost was calculated for each cost category, such as staff costs, material costs, and overhead costs. The supplementary information – table C provides an overview of the calculation of the unit cost per department.

To calculate the cost per nursing day per type of ward (surgery, internal medicine), total costs were divided by the number of patients days adjusted with a weight for the care intensity of each patient day. This care intensity per patient day was based on the Belgian Nursing Minimum Dataset (FOD Volksgezondheid, 2019; Sermeus et al., 2008). This is a legally required registration during 60 days per year of the care intensity per admitted patient (4 times 15 days distributed over the year).

Step 6: Calculation of costs per patient

In step six, the costs per patient visit were calculated. Therefore, for each patient the direct costs for implants and pharmaceuticals were distracted from the pharmacy data. For all other activities performed, the claims data and other activity data provides information on the services performed per patient (emergency visit, length of stay per type of nursing department, minutes of surgery time, radiological examinations, …). These services were multiplied by their respective unit cost. The result is a database with an overview of the processes and costs per patient visit (for patient stays, day care and ambulatory care).

Step 7: Aggregation on DRG and service level

Subsequently, the costs were aggregated on a DRG and service level (e.g. OR, ward, …). DRGs are only registered per patient stay. As a result, it was not possible to calculate the cost of the total care pathway in the hospital based on this DRG-registration.

Patients who have been hospitalized in two different fiscal years were excluded from the calculation per DRG. Also, small patient groups with less than five patients per combination of DRG and SOI and per hospital were excluded from the benchmark.

Results

The study aims to address the following research questions: (1) How can we measure costs? (2) Is it feasible to compare costs on a pathology level in a benchmark with multiple hospitals? (3) Which assumptions and critical success factors should be taken into account? (4) What are the learnings from the benchmark?

Research question 1: Measurement of costs

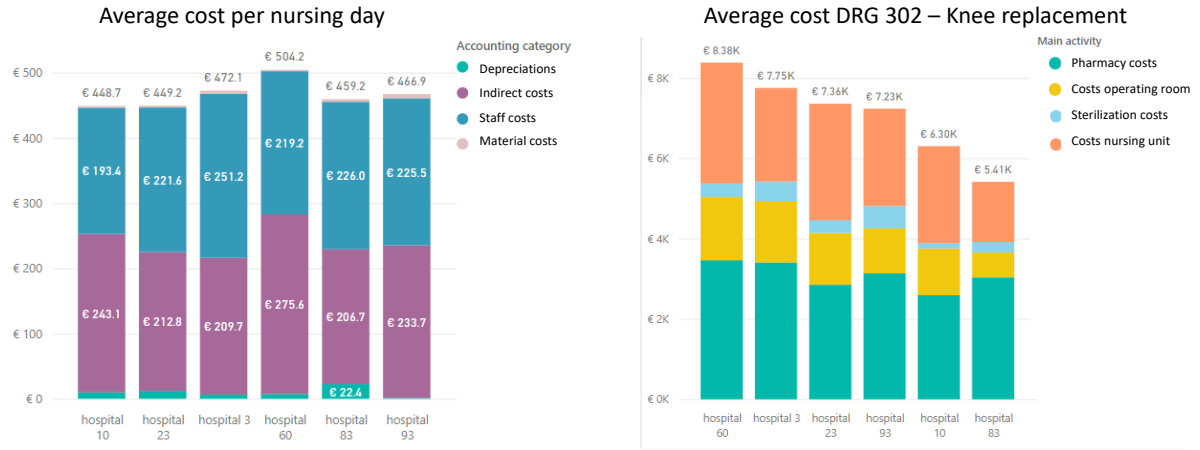
This research question was answered in the Material and Methods section: 'Method for cost calculation'.

Research question 2: Feasibility to compare costs on a pathology level

It was feasible to set up a benchmark to compare costs on a pathology level for multiple hospitals. However, the costs could only be aggregated per patient stay, as no DRG or other registration was available for the full cycle of care.

The benchmark was presented to each hospital in the form of two dashboards: (1) a comprehensive dashboard offering a detailed analysis of the costs per patient stay, DRG, and service within their own hospital, and (2) an aggregated benchmark dashboard with costs per stay (per DRG and severity), in which the hospitals were anonymized. The results were visualized using Microsoft PowerBI, while the models were programmed in R.

Upon receipt of the initial benchmark in February 2022, outliers were detected in the results of each hospital. These outliers were reported to the hospitals and investigated in collaboration with them, revealing that the discrepancies were due to data delivery or allocation issues. For example, the department labels were incorrect, or the hospital days were recorded on the department of admission like the emergency department instead of the actual department. To resolve these issues, the hospitals collected the correct data and the models were corrected. In May 2022, the hospitals received an updated version of the benchmark with the detected outliers resolved.



<u>Figure 5</u>: Examples of views available in Benchmark: Average cost per nursing day per hospital per type of cost and Average cost per contact for a total knee arthroplasty

Following the delivery of the benchmark, a user meeting was conducted in June 2022 with participation from the CFO and project leader of the cost study from each hospital. The meeting facilitated the discussion of results and mutual learnings between participants. It also provided an opportunity for hospitals to propose improvement ideas and vote on collected ideas. The top three improvement suggestions included (1) the ability to compare costs of the same DRG in day care versus hospitalization, (2) insights into the improvement potential in euros relative to other hospitals, and (3) detailed views on the claims data.

Research question 3: Assumptions and critical success factors

During the interviews, assumptions and critical success factors were formulated about the data collection, the method and the results of the cost calculation.

The data collection took several days per hospital. In the interviews, hospitals pointed out that it is important that one person per hospital takes the coordinating role in the data collection. Five of the six hospitals have a data warehouse. For them it was easier to collect the data than for the hospital without one. Especially the pharmacy data was difficult to deliver for this particular hospital and manual corrections on the data had to be made.

During the interviews, recommendations were formulated for each step in the cost calculation process.

In the first step, standardizing the accounting information across different hospitals was a significant challenge. The hospitals emphasized in the interviews that it is crucial that someone with in-depth knowledge about the hospital's general ledger is involved in the process. The hospitals highlighted the importance of understanding how costs are registered across various departments in different hospitals. For instance, some hospitals record logistic support in the OR directly under the OR, while others record it in a general cost center. Interviewees suggested that in the future agreements with benchmarking hospitals should be made in advance to standardize cost registrations rather than attempting to standardize them retrospectively. According to the interviewees, it is an

advantage that the dashboard provides a clear overview of the changes made to the cost structure in order to standardize costs (as shown in the supplementary information of this chapter).

In the second step, costs of the overhead departments were allocated to the medical cost centers. All included hospitals use the legal allocation keys (see overview in the supplementary information of chapter 2). They see this as a good example of standardization across hospitals. However, one of the interviewees pointed out that also in these legal keys, differences in interpretation are possible. For example, while food is allocated by the number of food days, this definition is not clearly specified resulting in differences among hospitals regarding the inclusion of day care patients. Additionally, while allocation keys offer a useful approximation of actual costs, they are not always reflective of the true cost. For instance, although cleaning is allocated based on the square meters of each department, in reality, cleaning an OR requires more time than cleaning an administrative area.

In the third step, direct costs for implants and pharmaceuticals are allocated to patients based on data extraction of the registrations in the pharmaceutical department. Hospitals hold the assumption that direct costs related to implants and pharmaceuticals are comparable across facilities. However, in the interviews they highlighted the need for a more thorough comparison of these costs to validate this assumption.

Regarding the fourth step, the collection of activity information, registrations are performed according to government-mandated regulations. However, the interviews revealed that there are still differences between hospitals in the interpretation of these regulations. For example, the severity of illness can differ between hospitals based on the quality of the registrations in the hospitals.

According to the interviewees, the methods used in step 5 to calculate a unit cost based on allocation keys is a very logical methodology to use. However, this approach may lead to a disconnection from the actual costs. For instance, in the OR, costs are determined by dividing them by the number of minutes a procedure takes to complete, based on the assumption that longer operations consume more resources. This method does not account for the fact that one or more nurses may be involved in an operation or that a short operation may require more materials than a longer one.

In calculating the costs per patient in step 6, the interviewees emphasize that it is important to keep in mind that the unit cost is based on the department's average, while in reality, the amount of care received by individual patients may vary.

Regarding step seven, the aggregation on DRG and service level, the interviewees highlighted an important issue. In Belgium, hospitalizations and day-care stays are categorized by a DRG and SOI, but ambulatory care is not linked to a DRG, making it difficult to calculate the cost of the entire care cycle within the hospital. This limitation of the current registration system was emphasized as a significant disadvantage.

In comparing the costs between hospitals, the interviewees highlighted two attention points. A first attention point is that hospitals that recently built a new hospital have higher depreciations, which makes correct comparison between hospitals difficult. Also, these depreciation rates do not always correspond to the actual lifespan. For instance, for equipment, the depreciation rates vary between 10% and 20% (see: table in the supplementary information of chapter 2).

Research question 4: Learnings from the benchmark

The hospitals received the benchmark at the end of June 2022. As the interviews were performed in January-February 2023, the hospitals already had 6 months of time to work with the benchmark. The interviewees identified three areas of learnings from the benchmarking process: comparability of results, utilization of results, and improvement ideas.

In comparing the results, the hospitals learned that despite the fact that the accounting rules are the same, there are still significant variations in their practical implementation. Some adjustments were already made in the benchmark to account for these differences, but more improvements can be made in the future. Additionally, to enable better comparison between hospitals, the interviewees would like to have a better understanding on how costs are recorded in each hospital, as well as more information about each hospital, such as FTE per department and per profile, and the services being utilized, such as a stroke unit and Cath lab.

In using the results, only one of the six interviewed hospitals already used the insights of the benchmark for improvement projects. In this hospital, analysis per department and per specialism were made. The results were presented to the board of directors, the management committee and the medical department heads. Also, detailed analysis per specialism were made and discussed by the medical director with every medical department head. Based on these discussions, actions were defined. This hospital learned from the benchmark that the improvement potential is the largest in the OR. This resulted in a more profound analysis of the OR occupation data per specialism outside of this research. The interviewees of this hospital emphasized that support from higher management is necessary to realize the improvement potential and that it is important to learn from the trends instead of the exact calculations.

Two other hospitals have concrete plans to use the results. They want to select 3 DRGs and form a working group with clinical and financial expertise for each DRG to discuss the differences of their own processes and costs in comparison to the other hospitals and to formulate improvement actions. The remaining hospitals have not used the results yet. These hospitals cite reasons such as no clear roles, lack of time, and a need for extra training and support. All hospitals expect that the insights will be very useful when the government introduces pathology financing per DRG, as announced by the Minister of Public Health (Vandenbroucke, 2022). This will enable them to see whether the pathology fee is sufficient to cover the costs. Also, the interviewees point out that the Belgian government requires hospitals to work more closely together, so they expect that the insights gained from the benchmark will facilitate strategic discussions with network partners in the future.

Following the delivery of the benchmark, a user meeting was conducted with participation of the CFO and project leader of the cost study from each hospital in June 2022. The interviewees consider this user meeting to be a crucial step towards gaining insights into each other's data and learning from one another. They suggest that such meetings should be conducted at least yearly.

Also, several improvement ideas were formulated. One suggestion was to expand the number of hospitals participating in the benchmark, which would enable comparison between different types of hospitals. Another idea was to include outcome indicators for each pathology, allowing hospitals to focus on both cost and outcomes. A third suggestion is to have more profound insights in the included personnel costs per department (e.g. logistic staff included in the department cost or in the overhead costs). Additionally,

hospitals expressed a desire to be able to compare data between different campuses of one hospital. Regarding the presentation of results, interviewees suggested creating a clear report that highlights areas for improvement, and the ability to select multiple DRGs for comparison. Finally, they recommended adding extra views on claims data to gain more detailed insights.

Discussion

The goal of this research was to evaluate the feasibility of establishing a benchmark on the cost and process data of hospitals in Belgium. In this discussion section, we analyze some of the methodological obstacles encountered, provide policy suggestions, and propose areas for future research.

Several attention points can be formulated related to the benchmark. A first attention point deals with the accuracy of the cost calculation. The overall method used in the benchmark is top-down micro-costing per DRG and SOI. This method entails identifying resources at a detailed patient level, while each cost component is valued by an average unit cost per patient. A more precise cost calculation method on a patient level is bottom-up costing by performing time registrations and costs of material registrations per patient (Christou et al., 2022). However, the question is how accurate the cost calculation has to be. According to Drummond et al. (2015) costing can take considerable time and effort and it is important to make a judgement on how accurate cost estimates need to be within a given study. Also, different levels of accuracy can be applied on different cost items depending on the importance of the cost category in the overall costs. Consequently, for certain cost studies, a more detailed measurement of costs may be necessary than foreseen in the current benchmark.

Second, hospitals that recently constructed new facilities have higher depreciations and the depreciation rates used may not always correspond to the actual lifespan, which makes it difficult to make correct comparisons between hospitals. In an international comparison (Špacírová et al., 2022), it was found that six out of nine European countries do not include depreciation of buildings in the cost calculation required for funding. In the benchmark, it is possible to exclude these costs. According to Christou et al. (2022), capital costs such as infrastructure and equipment should be annualized based on their real lifespan, which is more correct than the legally mandated annual depreciation percentages used in the benchmark. This is an area of improvement in the current benchmark.

Third, nursing costs are a significant component of hospital costs, and accurate allocation is essential. The unit costs of the wards are calculated based on the number of patient days weighted for care intensity. Pirson, Delo et al. (2013) also concluded that the calculation of nursing cost per DRG should be based on nursing activity data. Additionally, Chiang (2009) emphasized the need to differentiate between direct and indirect nursing care, as activities like record-keeping, administration, communicating with families and physicians, and preparing patients for discharge are essential components of nursing care but are not captured by the present intensity weights.

Fourth, the use of surgical time as a proxy for resource consumption in operating rooms was found to have limitations. Research showed that there is not a high correlation between the cost of disposable material in the OR and the surgical time. Therefore, for more accurate cost calculation, empirical data or itemized lists should be used for the calculation of costs of disposable materials for each patient (Christou et al., 2022; Delo et al., 2015). However, none of the hospitals included in the study had this information available, highlighting the need for more detailed registration of material use.

Fifth, activity data registrations are performed according to regulations-mandated by the government. However, the interviews revealed that there are still differences between hospitals in the interpretation of these regulations. In international research this phenomenon is called upcoding or down coding. Upcoding is defined as classifying patients in diagnosis-related groups codes associated with larger payments. Several researchers delivered evidence for this phenomenon in the USA, Portugal and France. (Barros & Braun, 2017; Geruso & Layton, 2020; Milcent, 2021)

Subsequently, an important policy recommendation can be made related to the calculation of costs of the full cycle of care. In Belgium, hospitalization and day-care stays are categorized by DRG and SOI, but ambulatory care is not linked to a DRG, making it challenging to gain insights into activities performed and accurately calculate costs of the full cycle of care within the hospital. The Netherlands for example has implemented a Diagnosis Treatment Combination (DBC) system that provides gradual records of all activities performed during the full cycle of care within the hospital, allowing for more accurate cost calculation (NZA, 2020). Also, in the United Kingdom (UK), the National Health Service (NHS) has set up a Patient Level Information and Costing System (PLICS) to calculate patient level costs (NHS, 2023a). The data collection has been designed to link costs of Emergency care, Admitted patient care and Outpatients costs to Hospital Episode Statistics data at record level to permit analysis such as cost by primary diagnosis (NHS, 2023b). As the Belgian government aims to switch to a prospective all-inclusive flat rate per pathology for hospital care based on justified costs, including pre- and post-hospitalization costs (Vandenbroucke, 2022), implementing a registration system that covers the care pathway at the hospital will be necessary.

Finally, there are several areas for further research. First, this research focusses on the cost component in VBHC, more specifically on hospital costs as this is an important source of healthcare expenditures. In future research, this focus can be expanded to other care givers. In Sweden, the National Board of Health and Welfare and Sweden's Municipalities and Regions developed a detailed top-down micro-costing methodology with separate procedures and databases for inpatient care, outpatient care and psychiatric care. For outpatient contacts, the CPP database contained in 2019 16.5 million contacts. These DRG costs are updated annually.

Second, it would be very interesting to integrate quality parameters into the research. In step six of the methodology, a database is created with an overview of the processes and costs per patient visit. Since all patient visits are included in the database, these costs can be linked to other systems and databases, like electronic health records, clinical or Patient Reported Outcomes or cancer registries (Visscher et al., 2017).

Third, international comparison of costs and activities on a DRG and severity level would be a very interesting area of further research. Common Data Models like the Observational Medical Outcomes Partnership (OMOP) are more and more created to provide standardized vocabularies to facilitate this comparison (Haberson et al., 2019).

Conclusion

With the delivery of the benchmark, a first step is taken. It will be important to further improve the benchmark, to build up a database over several years to show evolutions and to expand the number of hospitals included in the benchmark and to include outcome indicators in the benchmark.

Supplementary information - chapter 2

Supplementary information – Table A: List of data sources and the required fields per source

Data source	Necessary data fields
General Ledger	General ledger account code General ledger account description Cost center code Cost center description Closing balance debit Closing balance credit
Finhosta	Overview legal allocation keys
Claims data	Patient and visit number (pseudonymized) Admission date Discharge date Performance date Nursing unit label Performing specialism Treating specialism Invoiced amount total Nomenclature code
Operating room	Visit number (pseudonymized) Performing specialism OR room date in OR room hour in OR room date out OR room hour out
DRG registration	Visit number (pseudonymized) DRG – code Degree of severity
Sterilization	Visit number (pseudonymized) Number of sets
Pharmacy	Visit number (pseudonymized) Article code Article name Prescribing specialism Quantity administered Cost administered quantity Article ATC code Level 5

Supplementary information – Table B: Legally defined temporary cost centers and allocation keys

Temporary cost center	Allocation keys (step down allocation)
Depreciation	m^2
Financial expenses	m^2
General expenses	m^2
Maintenance	m^2
Heating	m^2
Administration	FTE
Laundry	Kg laundry
Food	Food days
Management nursing department	FTE nursing
Mortuary	Deceases
Medical secretary and DRG registration	Hospital stays

Supplementary information – Table C: Overview of the calculation of the unit cost per cost center

Department	Method (1)	Resource use – standard data available	Source of data	Unit cost
Emergency unit	WS	# emergency visits	Claims data	Cost per visit
Sterilization	WS	# sterilized sets per patient	IT registration system of the sterilization unit	Cost per sterilized set
OR	WS	# minutes in the OR / patient	OR registration	Cost per minute
Surgery nursing departments Internal medicine nursing departments Pediatric nursing department Maternity department Neonatal care department Geriatrics nursing department	RVU	# patient-days per type of department Weight: legal registration of care intensity (during 4 weeks/year)	Claims data Legal registration database (VG-MZG)	Weighted cost per nursing day per type of department
Other nursing departments (revalidation, palliative care, …)	WS	# patient-days per type of department	Claims data	Cost per nursing day per type of department
Day care	RVU	# day care visits RVU: amount of the reimbursement per type of day care visit.	Claims data	Weighted cost per day care visit
Intensive care	WS	# patient-days	Claims data	Cost/nursing day
Laboratory Pathology Radiology – NMR Radiology – CT Radiology – echo Radiology – scan	RVU	Type of test: detailed claims data per activity RVU: weight nomenclature	Claims data	Weighted cost per activity
Rehabilitation	WS	# sessions Weight: duration of the session	Claims data	Weighted cost per session
Pharmacy	 WS	Implants, pharmaceuticals, certain materials used: direct cost registration in pharmacy IT system Other costs: number delivered	Pharmacy IT system	Direct costs Cost/delivery of a medicine
Radiotherapy		No accurate claims data / other data available – reform by the government in progress – for now excluded		/
MD activities (consultation, surgery, …)	WS	# activities per MD and type of activity Weight: value of each activity	Claims data	Cost/activity

(1) WS = weighting statistics; RVU = relative value units

Supplementary information – Interview guide of the benchmark

QUESTION 1: Why did you enter the benchmark?

QUESTION 2: What things did you learn from the benchmark?

QUESTION 3: How do you use/think you will use insights for policy within the hospital?

QUESTION 4: How do you create support in the organization for this project?

QUESTION 5: What concerns and assumptions should be taken into account when setting up the benchmark?

1. In terms of data collection
2. In terms of methodology
    a. Step 1: standardization of cost accounting and comparability
    b. Step 2: allocation of overhead cost centers to medical cost centers based on legal allocation keys
    c. Step 3 direct costs
    d. Step 4 collection of activity information
    e. Step 5: calculation of a unit cost
    f. Step 6: calculation of a cost per patient
    g. Step 7 aggregation on DRG and service level
3. In terms of results
    a. Comparability of results
    b. Controls you wish to make
    c. Exclusion of certain costs (e.g. doctors' costs)

QUESTION 6: What could be further improved about the benchmark?

Supplementary information – Step by step overview of the manipulations in the General Ledger

Cost centre	0. Originele boekhouding	1. Te excluderen kostenplaatsen en/of account categorieën (afboeking)	2. Te verplaatsen kostenplaatsen (afboeking)	2. Te verplaatsen kostenplaatsen (nieuwe verdeling)	3. BFM toewijzen (afboeking)	3. BFM toewijzen (nieuwe verdeling)	4. VIPA toewijzen (afboeking)	4. VIPA toewijzen (nieuwe verdeling)	5. Indirecte kosten toewijzen (afboeking)
						-€ 86,857.45			
010 Financiële lasten						€ 186,584.72			-€ 186,584.72
020 Algemene onkosten	€ 131,963.67					€ 648,983.14			-€ 780,946.81
030 Onderhoud	€ 287,593.67					€ 2,485,934.32			-€ 2,773,527.99
040 Verwarming	€ 125,067.55					€ 191,591.40			-€ 316,658.96
050 Administratie	€ 2,412,238.50					€ 2,759,762.87			-€ 5,172,001.37
060 Wasserij - Linnen	€ 17.06					€ 663,836.90			-€ 663,853.96
070 Voeding	€ 197,420.31					€ 1,494,349.12			-€ 1,691,769.44
090 Medische kosten	€ 27,777,083.87				-€ 25,618,641.09	€ 7,295,612.62	-€ 1,068,976.28		-€ 8,385,079.12
091 Directie nursing + middenkader	€ 51,875.82								-€ 51,875.82
110 Eredienst	€ 382.18								-€ 382.18
120 Mortuarium	€ 25,791.32								-€ 25,791.32
140 Medisch Secretariaat	€ 18,055.60								-€ 18,055.60
142 MKG	€ 32,752.02								-€ 32,752.02
150 Spoedgevallen	€ 70,476.05			€ 2,121.77	-€ 1,758.82	€ 1,148,704.24			
160 Sterilisatie	€ 38,897.38					€ 194,023.86			
180 Operatiekwartier	€ 591,738.82			€ 8,192.22	-€ 3,794.69	€ 2,032,096.24			
181 Gipskamer	€ 196,789.44								
190 Bloedbank	€ 814,537.83	-€ 814,537.83							
190Z01 Bot- en weefselbanken									
210 Heelkunde	€ 1,991,202.66			€ 24,465.89	-€ 1,528,141.27	€ 2,485,758.44		€ 641,385.77	
220 Geneeskunde	€ 1,581,963.29			€ 23,475.94	-€ 1,146,094.45	€ 2,742,117.94		€ 106,897.63	
230 Pediatrie	€ 509,030.87			€ 1,484.92	-€ 324,941.86	€ 479,551.36			
260 Materniteit	€ 511,206.20				-€ 291,255.90	€ 1,061,971.27			
300 Geriatrie	€ 1,118,746.93		-€ 119,642.45	€ 30,052.03	-€ 661,418.09	€ 3,020,002.50		€ 106,897.63	
310 Sp									
310Z04 Sp-Locomotorisch	€ 2,521,398.68			€ 13,364.32	-€ 2,473,782.49	€ 1,579,446.89			
310Z06 Sp-Palliatieve zorgen	€ 1,131,573.40			€ 5,020.46	-€ 1,104,381.60	€ 575,035.59			
320 Chirurgische Daghospitalisatie	€ 1,301,599.01			€ 636.40	-€ 507,111.06	€ 588,403.42			
370 Neuro Psychiatrie						€ 7,561.98			
370-390 Neuro Psychiatrie	€ 710,265.95			€ 13,930.00	-€ 567,159.53	€ 1,604,275.16			
Total	**€ 104,863,641.05**	**-€ 975,135.60**	**-€ 11,671,038.44**	**€ 11,671,038.44**	**-€ 35,894,456.74**	**€ 35,894,456.74**	**-€ 1,068,976.28**	**€ 1,068,976.28**	**-€ 20,099,279.29**

Supplementary information – Table D: Annual depreciation percentages

Type of cost	Depreciation percentage
Establishment costs:	
Cost of incorporation and contribution	33%
Other formation costs	33%
Interests	10%
Restructuring costs	33%
Intangible fixed assets	33%
Buildings:	
Buildings	3%
Other property rights on real estate	3%
Major repairs and maintenance	10%
Furnishing of the buildings	3%
Material for medical equipment	20%
Material for non-medical equipment and furniture:	
Furniture and equipment	10%
Rolling equipment	20%
Equipment and furniture for information processing	20%

Source: Koninklijk Besluit (2007)

Chapter 3: Onco@home: Comparing the costs and reimbursement of cancer treatment at home with the Standard of Care

Abstract

Objective

Oncological home hospitalization (HH) was implemented during a pilot period (2016-2022) to evaluate the feasibility of oncological HH in a Belgian context. In a first HH model, implemented by three Belgian hospitals, two home nursing organizations and a grouping of independent nurses, the blood draw and monitoring prior to intravenous therapy were performed by a trained home nurse at the patient's home the day before the visit to the day hospital. In a second HH model, implemented in one hospital, the administration of two subcutaneous treatments (Azacitidine and Bortezomib) for myelodysplastic syndrome and multiple myeloma were provided at home instead of in the hospital. A previous study on this pilot showed that oncological HH is a feasible and safe alternative for hospital care and improves the Quality of Life. The aim of this study is to investigate the cost and reimbursement of cancer treatment in these two HH models compared to the Standard of Care (SOC).

Methods

A bottom-up micro-costing study was conducted to compare the costs and revenues for the providers (hospitals and home nursing organizations) of the SOC and the HH models.

Results

Costs associated to HH for the providers (hospitals and home nursing organizations) are higher than the SOC in the hospital. Comparing revenues with costs, the research revealed that the reimbursement from the National Health Insurance (NHI) of HH for oncological patients is insufficient.

Conclusion

Costs of HH are higher and the reimbursement from Belgian NHI is insufficient to organize HH. As a result, HH for oncology patient is still limited in Belgium.

Introduction

Cancer care is evolving rapidly, with advances in treatment and increasing healthcare costs (Pisu et al., 2018). In the European Union, cancer care is responsible for 6.2% of all healthcare expenditure (Hofmarcher, 2019). Over the last two decades, health spending on cancer care has increased more rapidly than cancer incidence (Hofmarcher et al., 2020).

Home hospitalization (HH) is a possible approach to offer high-quality, patient-centered care and create value for patients. Alves et al. (2017) defined HH as "a service that provides active treatment by healthcare professionals in the patient's home for a condition that otherwise would require acute hospital inpatient care, and always for a limited time period".

This study is part of a larger research project to evaluate the feasibility of oncological HH in a Belgian context. The goal of this research project is to learn from the practical implementation of HH, to elaborate a roadmap for implementation, and to advise the government on the legal, financial, and other barriers and opportunities. Therefore, two HH models were implemented during a pilot period (2016-2022) with the support of a social profit organization, Kom op tegen Kanker. In a first HH model (HH1), implemented by three hospitals, two home nursing organizations and a grouping of independent nurses, the blood draw and monitoring prior to intravenous therapy were performed by a trained home nurse at the patient's home the day before the visit to the day hospital. In a second HH model (HH2), implemented by one hospital, the administration of two subcutaneous treatments (Azacitidine and Bortezomib) for myelodysplastic syndrome and multiple myeloma was provided at home instead of in the hospital.

In reviewing the literature, as part of this research project, Cool et al. (2018) found that a large majority of HH patients are satisfied with HH (12/13 studies) and prefers home treatment (7/8 studies). The review also revealed that HH might be considered as safe and has no significant effect on the reported Quality of Life (7/8 studies).

Subsequently, a Randomized-Controlled Equivalence Trial with a total of 148 participants (n=74 in each group) was conducted by Cool et al. (2021), confirming the viability and safety of the implementation of oncological HH while having no observable effect on patient-reported Quality of Life. HH1 led to a significant reduction of waiting time before therapy administration at the day care unit by 45% per visit (2 hours 36 minutes ± 1 hour 4 minutes vs. 4 hours ± 1 hour 4 minutes; $P < .001$). In total, 88% of the intervention group reported high levels of satisfaction with HH practices, while 77% reported a positive impact on their Quality of Life. Ultimately, 60% of participants in both groups opted for HH as the preferred intervention over the SOC.

However, little information is available on the costs of HH. The systematic review of Cool et al. (2018) revealed that only five studies compared the costs for oncological HH to the costs in the hospital. These studies considered different cost perspectives, including the NHI, the provider, and society, making cross-study comparisons challenging. In examining provider costs, King et al. (2000) demonstrated that providing chemotherapy at home is more expensive than in-hospital care, primarily due to increased nursing time in HH. Similarly, in a more recent study, Franken et al. (2020) found higher healthcare costs associated with home-based administration of subcutaneous trastuzumab, also because of increased nursing time (110 minutes for HH versus 38 minutes in a hospital setting). Rischin and Matthews (2001) also reported increased costs associated with HH treatments. On the other hand, Lüthi et al. (2011) concluded that home nursing results in a 53% cost benefit compared to hospital treatment. None of the cited studies compared the production

costs for the provider with the reimbursement from the NHI while reimbursement is a key success factor in the uptake of HH (Handley & Bekelman, 2019).

In the previous studies of this research project (Cool et al., 2021; Cool et al., 2018) was concluded that further research on the financial impact of HH models is needed. Therefore, the first objective of this study is to investigate the costs of the implemented HH models compared to the SOC. The second objective is to investigate whether the current reimbursement from the NHI of HH for oncological patients is sufficient to cover the costs for the providers (hospitals and home nursing organizations).

Material and methods

Scope

In this study, cost and revenues of oncology care were calculated from a providers' perspective for the standard hospital day care and for two HH models. The study focused on the hospital and home nursing costs. Doctors' activities were excluded from the study as medical doctors are independent and are reimbursed separately via a distinctive funding model. Additionally, pharmaceutical expenditures were excluded from the study as they vary widely based on the therapy utilized and are reimbursed according to a separate system. Finally, patient and family costs were ignored, as the main research question is what the costs and reimbursements are for the hospital and home nursing organizations, not what the total societal costs are.

Design

To calculate the costs, a bottom-up micro-costing study was conducted for the providers (hospitals and home nursing organizations). Bottom-up micro-costing is described by Tan et al. (2009) as the gold standard methodology for the costing of hospital services. Costs were calculated as described in the Belgian manual for cost-based pricing of hospital interventions, elaborated by the Belgian Health Care Knowledge Centre (Swartenbroekx et al., 2012). The average cost per care pathway was calculated for (1) staff, (2) materials, (3) traveling, and (4) other costs (cleaning, heating, laundry, catering, administration, general depreciation costs, etc.).

Revenues were gathered from the Belgian NHI. The Belgian hospital financing system for oncology day care patients consists of different elements: (1) A lump sum for nursing activities for preparation of patients, interventions as well as for after-care costs, costs of bedding and laundry, cleaning, heating,…; (2) A fee for service system for doctors' procedures (consultations, lab tests, radiology,…); (3) The reimbursement of pharmaceuticals, including chemotherapy. For the revenues of the hospital, only the lump sum for nursing activities was taken in scope of this study, as doctors' costs and pharmaceuticals were also excluded from the cost calculation. The lump sum specific for the administration of chemotherapy varies according to the administration of one or multiple products per visit. In home nursing, home nurses work in a fee for service system. Those fees were collected for the home hospitalization activities for HH1 and HH2.

Study intervention

The standard ambulatory hospital care process (SOC) entails the patient's arrival at the day hospital, where all necessary medical procedures are conducted. These include sample collection for blood analysis and anamnesis by an oncology nurse, blood analysis, data interpretation by the physician, consultation with the physician, preparation and administration of chemotherapy and follow-up, illustrated in Figure 6.

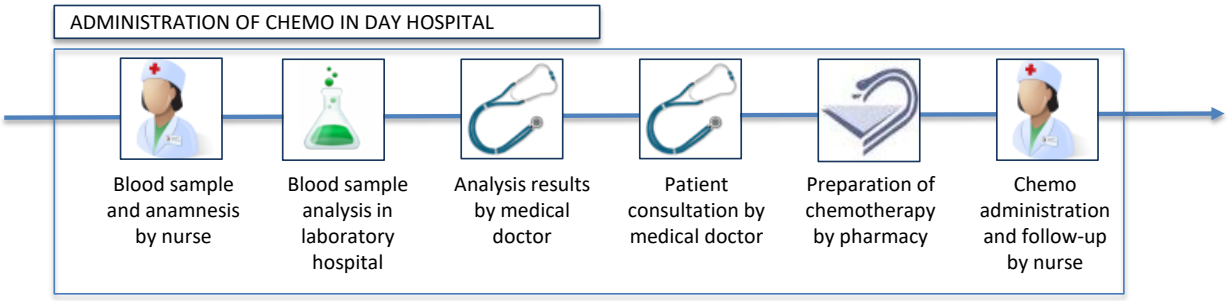


Figure 6: Standard of Care

In a first HH model (HH1), blood draw and anamnesis before intravenous therapy is performed by a trained home nurse at the patient's home the day before the hospital visit. By conducting these assessments one day prior to therapy administration (i.e., on day -1), oncologists are able to prescribe therapy and the pharmacy can prepare treatments in advance of patient arrival at the hospital, which reduces the waiting time before the administration of chemotherapy (Cool et al., 2021), see figure 7.

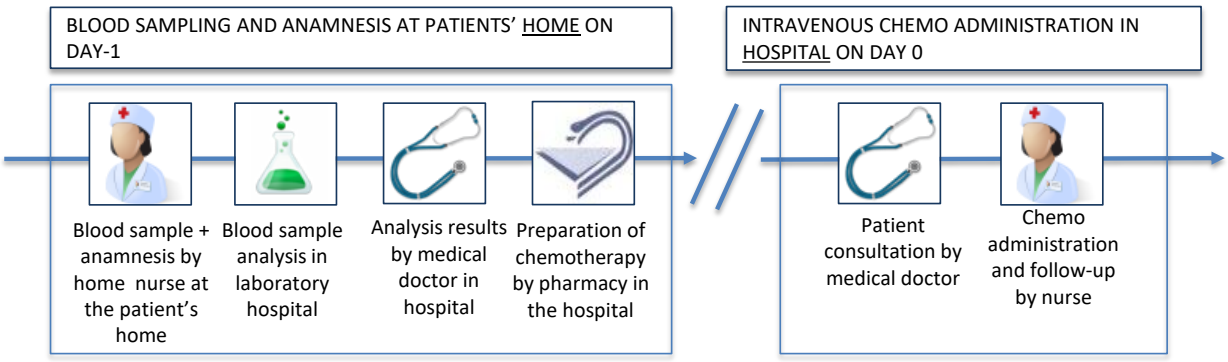


Figure 7: Home hospitalization model 1: Performing preparation in the home environment prior to intravenous therapy at the day hospital the next day

In a second HH model (HH2), the administration of two subcutaneous treatments (Azacitidine and Bortezomib) for myelodysplastic syndrome and multiple myeloma are provided partly at home instead of in the hospital. In this study, the first administration per cycle and the administrations in the weekend are performed in the hospital. The other administrations are executed at the patient's home, after performing a telephone symptom burden survey. Those two treatments were selected because of the frequent visits to the hospital per treatment and the burden this brings for patients. Because of the financial barriers (explained further), only one hospital decided to participate in this HH2. In this hospital a hospital nurse administers the treatment at home.

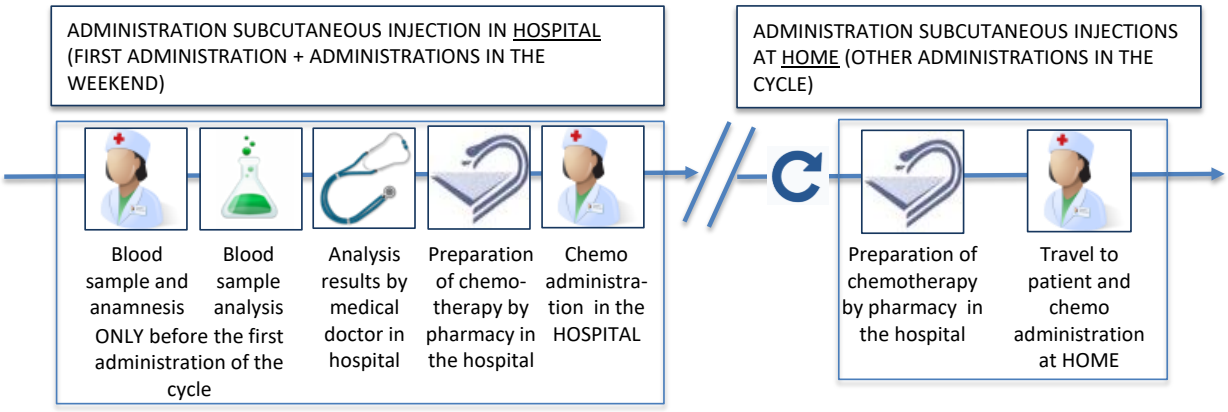


Figure 8 Home hospitalization model 2: the subcutaneous administration of chemotherapy in the home setting

For the cost and revenue calculation, a further subdivision in eight different types of care pathways was made, see Figure 9.

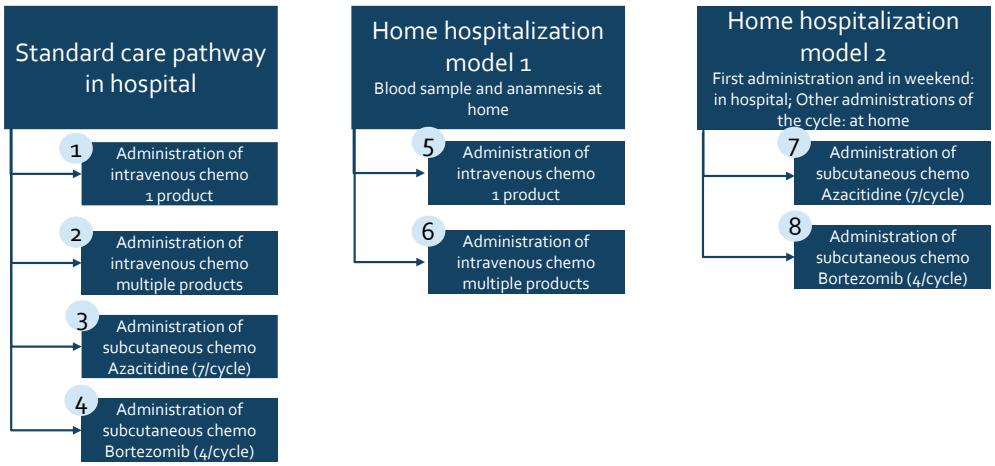


Figure 9: Overview of the types of patients identified for the cost calculation

In the SOC, a distinction was made between two types for the administration of intravenous chemo and two types for the administration of subcutaneous chemo. For intravenous chemo, the administration of one or multiple chemo products per day has an impact on the administration time. Also, the reimbursement for the administration of one product is lower than for the administration of multiple products. For subcutaneous treatment, a distinction was made between the subcutaneous administration of Azacitidine, with seven administrations per cycle, and the subcutaneous administration of Bortezomib, with four administrations per cycle. In HH1, a division in two groups is made: the administration of one product and the administration of multiple products, as in the SOC. In HH2, as in the SOC group, there was also a distinction made between the administration of Azacitidine and Bortezomib.

Data collection

Cost and revenue data for the year 2019 were gathered, as 2020 and 2021 were impacted by the COVID-19 pandemic in terms of costs. Data were collected in three hospitals for the SOC, in three hospitals and in two home nursing organizations for HH1 and in one hospital for HH2.

To calculate the staff costs, the average time of each activity and the cost per minute of each activity were calculated. Therefore, activities of the different care pathways were mapped in the three hospitals and two home nursing organizations. Subsequently, time registrations per activity were performed during the period between October 2020 and April 2021. In this period, there was a normal activity for oncological patients. Even though it was still during the COVID-19 pandemic, chemotherapy was delivered to patients in the hospital as before the pandemic.

To calculate the time per activity in the day care units of the three hospitals, nurses were followed during 12 days, 4 in each hospital, and the time of every activity and patient was registered. To simplify the data collection process, an excel macro was built with buttons to indicate at the start of each activity, after which the start time was automatically recorded (see supplementary information of chapter 3). To take all time into account, also the time not related to a patient of the followed nurses was registered (e.g. walking, administration, and logistical tasks).

In two hospitals, because of the architecture and scale of the day care unit, it was possible to register the time of all nurses active in the unit between 7 AM and 6 PM. In one larger hospital, only one nurse per day was followed during a full shift. In that hospital, 3 early shifts (from 7 AM to 4 PM) and one late shift (from 9 AM to 6 PM) were followed. For each activity directly related to a patient, the patient and room number was registered. After every registration day, all followed patients were allocated to the different care pathways together with an oncology nurse of the department. Not all patients could be allocated to one of the defined care pathways, as the day care unit also performs other treatments. In total, time registrations of 46 patient visits were included.

In HH1, the home nurses and administrative staff of two home nursing organizations self-registered the time of every direct and indirect activity during 2 weeks between September and December 2020 based on a comparable list of activities as in the hospital. In total, time registrations of 99 patients were collected. In the supplementary information the registration form with the list of activities is included.

HH2 was only implemented in one hospital on a limited number of patients. The visits to the patients were performed by an oncology nurse of the oncology day care center. In HH2 the oncology nurse performed time registrations of all direct and indirect time during 2 weeks. In total, time registrations of 15 HH2 patients were gathered during the period September-October 2020. In the supplementary information of chapter 3 the registration form with the list of activities is included.

The time not related to a patient of the followed nurses was added to the direct care time as a percentage of the direct care time per visit.

Subsequently, a cost-per-minute-per-profile was calculated. To do this, wage costs from the accountancy department of the three hospitals and two home nursing organizations were collected. To calculate the cost per minute, 1,605.2 hours/year of productive time was used (Swartenbroekx et al., 2012).

For the material costs, the oncology nurses in two hospitals registered all materials necessary in the SOC, HH1, and HH2 and collected the costs of each material from their accounting departments.

To calculate the travel costs, the nurses registered the distance to each patient during the time registration of HH1 and HH2. Based on this information, an average distance per patient was calculated. Per km an average cost of €0.35 was used, based on the kilometer allowance defined by the government (Federale Overheidsdienst Beleid en Ondersteuning, 2020).

For the administrative, logistic and coordinating staff in the day hospital, the total cost per profile per hospital was extracted from the accounting and HR information of 2019. To calculate the average cost per patient and per hospital, the cost per year was divided by the total number of day hospital patients.

For general overhead costs in the hospital, a mark-up percentage of 56.6% on direct costs was used for maintenance, heating, laundry, catering, administration, general depreciation costs, etc., as calculated in the Belgian manual for cost-based pricing of hospital interventions of Swartenbroekx et al. (2012), based on accounting information of all Belgian hospitals. At the time of the study, this was the best available information in Belgium and no more recent information was available.

In the included home nursing organizations, the financial departments calculated the overhead percentage for the costs of administration, buildings, management, … based on the accounting information of 2019. The average overhead percentage for these costs was 13.2% mark-up on staff costs.

Revenues

The average revenue per care pathway was calculated based on invoices and pricing information from NHI. Patient invoices of the year 2019 were collected in the hospitals (n = 4,669). In home nursing organizations, only a few activities (nomenclature numbers) can be charged to the NHI. These charges and their implementation rules were gathered during interviews with the nursing coordinators of the two home nursing organizations.

Assumption

In the cost calculation it was assumed that, in the short term, there would be no reduction of the overhead costs in the hospital per patient. The number of beds, m^2, staff, and so on will not change because of this project.

Results

The calculations of costs, revenues and financial results per care pathway were performed per type of care pathway. Eight different care pathways were distinguished (see figure 9).

- Care Pathways 1 and 2: Average of one visit to the day care center
- Care Pathway 3: Average of one visit, 7 visits per cycle, one blood test per cycle
- Care Pathway 4: Average of one visit, four visits per cycle, one blood test per cycle
- Care Pathway 5 and 6: Average of blood analysis at home performed by a home nursing organization and administration of chemo in the hospital
- Care Pathway 7: Average of one visit, 7 visits per cycle: three in the hospital and four at home performed by hospital oncology nurse at home, one blood test per cycle
- Care Pathway 8: Average of one visit, four visits per cycle: one in the hospital and three at home performed by a hospital oncology nurse at home, one blood test per cycle

Input parameters

All input parameters (unit cost per minute per profile, average time per activity and travel time in minutes per visit, material costs and revenues) are included in the supplementary information. For the travel costs, the average distance in HH1 was 9.46 km (+/-3.9 km SD) and in HH2 11.33 km (+/- 6.4 km SD).

Cost calculation

Based on the input parameters an average cost per visit per type of care pathway was calculated for the SOC, HH1 and HH2.

Table 8 gives the costs and revenues in the SOC.

Table 8: Calculation of costs and revenues per visit – SOC

Care pathway	SOC Administration in hospital Calculation base = 1 visit to the day care center Average costs and revenues per visit			
	Intravenous treatment 1 product	**Intravenous treatment, multiple products**	**Subcutaneous treatment Azacitidine**	**Subcutaneous treatment Bortezomib**
	1	2	3	4
TOTAL COSTS	€170.8	€220.9	€121.2	€122.6
Cost of care time nurses (direct + indirect) (1)	€65.4	€92.2	€42.1	€42.1
Cost of coordination, logistics and administration day care unit (2)	€33.6	€33.6	€33.6	€33.6
Material cost (3)	€10.1	€15.3	€1.7	€2.6
Hospital overhead costs (4)	€61.7	€79.8	€43.8	€44.3
TOTAL REVENUES	€124.1	€166.1	€124.1	€124.1
RESULT (Revenues – Costs)	-€46.7	-€54.7	€2.9	€1.5

(1) = Time * cost/minute (see supplementary information)
(2) = Total cost coordination, logistics and administration / # day patients
(3) = Material for blood draw in hospital + material for administration of chemo (see supplementary information)
(4) = +56.6% on the standard care pathway

Based on the performed calculations, we found that the SOC for intravenous products is loss-making (-€46.7 for the administration of one product and -€54.7 for the administration of multiple products). For subcutaneous treatment, the result is slightly profitable (+€2.9 for Azacitidine and +€1.5 for Bortezomib). The reason is that the revenues per visit are the same: a fixed fee of €124.1 for the administration of intravenous chemo 1 product or subcutaneous treatment and €166.1 for the administration of multiple products, while the administration of intravenous chemo is more time-intensive than the administration of subcutaneous treatment.

Table 9: Calculation of costs and revenues per visit, HH1

	Average costs and revenues per visit Intravenous treatment 1 product 5	Intravenous treatment multiple products 6
TOTAL COSTS **Cost hospital + home nursing**	€221.3	€271.3
Day care oncology unit	€147.0	€197.0
Cost of care time nurses (direct + indirect) (1)	€50.3	€77.1
Cost of coordination, logistics and administration	€33.6	€33.6
Material cost	€1.4	€6.5
Overhead costs (2)	€61.7	€79.8
Home nursing	€74.3	€74.3
Total staff costs	€54.6	€54.6
Transport costs	€3.3	€3.3
Material costs	€9.2	€9.2
Overhead costs (3)	€7.2	€7.2
TOTAL REVENUES	€157.7	€199.7
Hospital	€124.1	€166.1
Home nursing	€33.6	€33.6
RESULT	- €63.6	- €71.6
Hospital	- €22.9	-€30.9
Home nursing	-€40.7	-€40.7

(1) Reduction of 19.6 minutes care time for blood draw and symptom control as this is performed at home
(2) +56.6% on the standard care pathway
(3) + 13.2% on staff costs in HH1

Table 9 gives the average costs and revenues per visit for HH1. In the cost calculation it was assumed that, in the short term, there would be no reduction of the overhead costs in the hospital per patient. The number of beds, m^2, staff, and so on will not change because of this project. Therefore, cost of coordination, logistics, administration and overall overhead costs in the hospital were assumed to remain the same in HH1 and HH2.

In table 9, the costs and revenues of HH1 in the day care oncology unit and in home nursing were calculated. The blood draw and symptom control are performed at home. As a result there is a reduction of the care time and the cost of the nurses in the hospital. The cost of home nursing is calculated as €74.3. In home nursing, home nurses receive a fee of €33.6, which is not sufficient to cover the full cost of the transport, the care time, administration… of the home nursing organization. Also, in the hospital, HH1 is still loss-making. As a result, both the administration of intravenous treatment of one (-€63.6) and of multiple products (-€71.6) is loss-making in total.

Table 10: Calculation of average costs and revenues per visit, HH2

	Average costs and revenues per visit – subcutaneous treatment at home Azacitidine 3 visits in hospital, 4 at home 7	 Bortezomib 1 visit in hospital, 3 at home 8
TOTAL COSTS **Cost hospital + home nursing**	€130.7	€135.1
Day care oncology unit	€97.1	€91.1
Cost of care time nurses (direct + indirect)	€18.1	€10.5
Cost of coordination, logistics and administration	€33.6	€33.6
Material cost	€1.7	€2.6
Overhead costs)	€43.8	€44.3
Administration at home by hospital oncology nurse	€33.5	€44.6
Total staff costs	31.7	€41.6
Transport costs	€1.9	€3.3
TOTAL REVENUES	€56.2	€34.7
Hospital (3)	€53.2	€31.0
Home nursing: (4)	€3.0	€3.7
RESULT	- €74.4	- €100.4
Hospital	- €43.9	-€60.0
Home nursing	-€30.5	-€40.4

(1) Cost of SOC * # visits in hospital) / total # visits per cycle
(2) +56.6% on the standard care pathway
(3) (Revenues of SOC * # visits in hospital) / total # visits per cycle
(4) (Revenues per visit * # visits in hospital) / total # visits per cycle

Table 10 gives the average costs and revenues per visit for HH2. In this calculation, the average of 1 visit is calculated. In home nursing, the fee is only €5.3 per visit, while this is €124.1 in hospital.

For Azacitidine, there are 7 visits per cycle: three in the hospital and four at home performed by a hospital oncology nurse at home and one blood test per cycle during the first visit to the hospital. The average result per administration is -€74.4. For Bortezomib, there were four visits per cycle: one in the hospital and three at home performed by a hospital oncology nurse at home, one blood test per cycle. The average result per administration is -€100.4.

Table 11: Comparison of HH1 and HH2 to the SOC

	Difference HH 1 – SOC		Difference HH 2 – SOC	
	Intravenous treatment 1 product	Intravenous treatment multiple products	Subcutaneous treatment Azacitidine	Subcutaneous treatment Bortezomib
TOTAL COSTS Cost hospital + home nursing	+€50.4	+€50.4	+€9.5	+€12.4
Day care oncology unit	-€23.9	-€23.9	-€24.1	-€31.6
Total staff cost	-€15.1	-€15.1	-€24.1	-€31.6
Material cost	-€8.8	-€8.8	+€0.0	+€0.0
Overhead costs (1)	+€0.0	+€0.0	+€0.0	+€0.0
Home nursing	+€74.3	+€74.3	+€33.5	+€44.0
Staff costs	+€54.6	+€54.6	+€29.2	€38.3
Transport costs	+€3.3	+€3.3	+€1.9	€2.5
Material costs	+€9.2	+€9.2	+€0.0	€0.0
Overhead costs (2)	+€7.2	+€7.2	+€0.0	€0.0
TOTAL REVENUES	+€33.6	+€33.6	-€67.9	-€89.4
Hospital	+€0.0	+€0.0	-€70.9	-€93.1
Home nursing	+€33.6	+€33.6	+€3.0	€3.7
RESULT (Revenues – Costs)	- €16.9	- €16.9	- €77.4	- €101.9
Hospital	+€23.9	+€23.9	- €46.8	- €61.5
Home nursing	-€40.7	-€40.7	-€30.5	-€40.4

(1) +56.6% on of the standard care pathway

(2) + 13.2% on staff costs

As illustrated in table 11 costs are overall higher in HH1 than in the SOC (+€50.4). There is a reduction in costs in the hospital by moving the blood draw to the home setting (-€23.9), but the costs in home nursing are higher (+€74.3). We also see that the revenues in home nursing are insufficient to cover the costs. In HH1, the revenues in home nursing are €33.6 per visit and in the hospital the revenues remain the same. As a result, the loss is €16.9 higher in HH1 than in the SOC.

In comparing HH2 to the SOC, there is also an increase in costs between the SOC and HH2 (+€9.5 for Azacitidine and +€12.4 for Bortezomib). This cost difference between HH2 and the SOC is due to the travel time of the nurse to administer the chemo at home. However, there is almost no funding for subcutaneous administration in home nursing. If the product is administered in a day hospital, the hospital receives revenue of €124 per administration, while in home nursing the funding is €5 per visit. As a result, the average revenue per administration decreases substantially (-€67.9 for Azacitidine and -€89.4 for Bortezomib), while the costs increase slightly (+€9.5 or +€12.4). As a consequence, the average result decreases in HH2 compared to the SOC, with €77.4 for Azacitidine and €101.9 for Bortezomib.

Discussion

A previous Randomized-Controlled Equivalence Trial (Cool et al., 2021) focused on the outcomes of HH. This study revealed that the implemented HH models are feasible and safe and that a large majority of patients is highly satisfied with HH and that it has a positive impact on their Quality of Life.

In this study, we focused on the costs and revenues. Based on the calculations and assumptions we made, we found that the costs are higher in HH1 than in the SOC (+€50.4). There is a reduction in costs in the hospital by moving the blood draw to the home setting (-€23.9), but the costs in home nursing are higher (+€74.3). We also see that the extra revenues in home nursing (+€33.6) are insufficient to cover the costs. When we compared HH2 to the SOC, the cost difference between the SOC and HH2 (+€9.5 for Azacitidine) was smaller than in HH1. This cost difference between HH2 and the SOC is due to the travel time of the nurse to administer the chemo at home. These results are in line with those of King et al. (2000), Franken et al. (2020), and Rischin and Matthews (2001), who concluded that home administration is more expensive than hospital administration.

However, our calculation did not take into account the efficiency gains that can be realized in the longer term. In HH1, as the blood test and the chemotherapy preparation are performed before the patient arrives in the day care clinic, the throughput time can be reduced. This allows better use of the available capacity in terms of beds and seats. The previous Randomized-Controlled Equivalence Trial (Cool et al., 2021) found that the HH1 model leads to a significant reduction of waiting time before therapy administration at the day care unit by 45% per visit (2 hours 36 minutes ± 1 hour 4 minutes vs. 4 hours ± 1 hour 4 minutes; $P < .001$). Also, in HH2 less capacity of beds and seats is necessary as the administration is performed at home. As a result, the use of beds and seats in the day care oncology unit can be optimized and more patients can be admitted with the same capacity. King et al. (2000) concluded that when the demand for chemotherapy exceeded ward capacity by up to 50%, home nursing could provide a less costly strategy than the expansion of a chemotherapy service in the hospital.

In comparing the revenues with the costs, based on the assumptions and calculations we made, we see that the current funding from the NHI of HH for oncological patients is insufficient, while reimbursement is a key success factor in the uptake of HH (Handley & Bekelman, 2019). Also, in the SOC for intravenous treatment the current funding is insufficient. However, starting July 1, 2023, the government has reassessed the reimbursement framework for HH. Reimbursement is now foreseen for the parenteral administration of chemo for minimum 3 days of cancer treatment (RIZIV, 2023a). Only specific therapies from a predetermined list are eligible for reimbursement (RIZIV, 2023b). The remuneration encompasses a lump sum for initiating home hospitalization. Additionally, it includes supervision fees for the physician specialist, fees for coordination and care coordination by nurses in both the hospital and home setting, lump sums for the preparation and delivery of the drug by the hospital pharmacist, fees for the home nurse administering drugs, fees for costs associated with equipment, and fees for the GP when their expertise is invoked. This will enable HH to expand. However, statistics on adoption are not yet accessible.

Our findings are limited by the fact that only three Belgian hospitals and two home nursing organizations were involved in the HH and we focused on 2 HH models. For the cost calculation, the number of patients and hospitals is limited, which has an impact on transport time and possible efficiency gains in organizing home nursing. Also, we did not

take into account the societal costs. Direct healthcare costs only represent a small proportion of the total societal costs of cancer. Other costs are: (1) direct costs outside the healthcare sector that can be completely attributed to an illness, like patient travel costs and modification of patients' home, (2) indirect costs which impact consumption of resources, like production loss due to mortality and morbidity, (3) intangible costs quantified in value of lost life years and value of lost quality of life and (4) other costs like informal nursing/home care (Bugge et al., 2021). HH will have an impact on the direct costs outside the healthcare sector, namely on patients' travel costs and on other costs, like costs of informal care givers. Further research on efficiency gains and societal costs of home hospitalization is necessary.

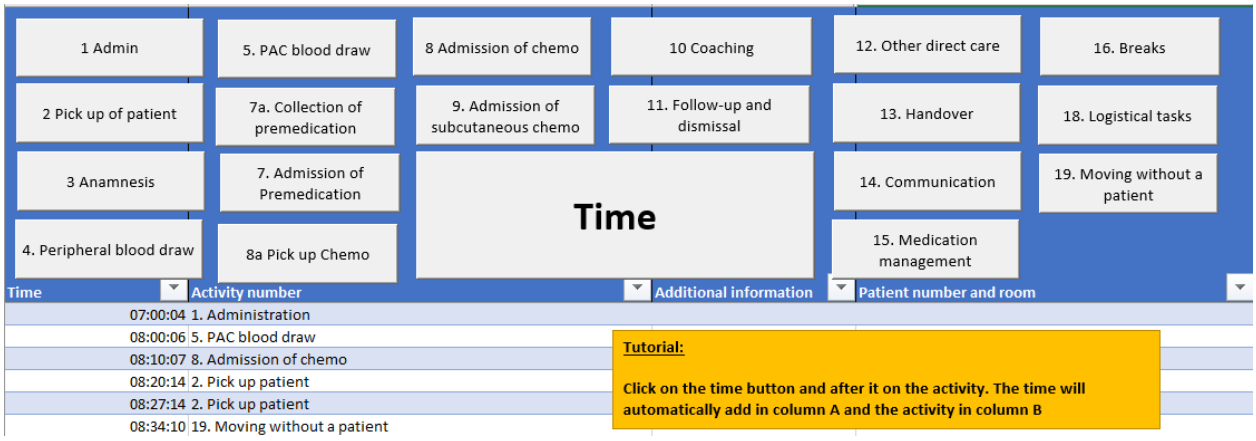
Even though the present study was only conducted in one country and included a limited number of patients, it provides new information on costs of HH. Oncological treatments are increasingly designed to be administered subcutaneously and orally, and most developed new drugs have increasingly favorable acute toxicity profiles. The latter allows for treatments to be given for longer period of time and to elderly patients, increasing the need for patient-friendly care pathways on the one hand and the need for day care unit capacity on the other hand. HH might be part of the answer to both of these questions.

Conclusion

A previous study showed that oncological HH is a feasible and safe alternative for hospital care and improves the Quality of Life. However, costs off HH are higher than the SOC and the funding from Belgian NHI is insufficient to organize HH. As a result, HH for oncology patients is still limited in Belgium. Reimbursement will be a key success factor in the uptake of HH. Therefore, starting July 1, 2023, the government has reassessed the reimbursement framework for HH for the parenteral administration of chemo for minimum 3 days of cancer treatment. This will enable HH to expand.

Supplementary information - chapter 3

Supplementary information – Figure A: Automatic registration form for shadowing



Supplementary information – Table A: Activities HH1

Activity in home nursing HH1	Time in total per day or per patient
Administrative preparation of a new patient	In minutes per new patient
Planning and calling patients to confirm visit	In minutes per day
Travel time to patient	In minutes per patient
Blood draw	In minutes per patient
Anamnesis, questionnaire on state patient, vital parameters	In minutes per patient
Transport of blood samples to hospital	In minutes per day
Registration in patient file	In minutes per patient
Communication (with General Practitioner, family, …)	In minutes per patient
Administration and other tasks	In minutes per day

Supplementary information – Table B: Activities HH2

Activity in home nursing HH2	Time in total per day or per patient
Administrative preparation of a new patient	In minutes per new patient
Planning and calling patients to confirm visit, call Medical Doctor, pharmacy, administrative processing	In minutes per day
Pick up medication	In minutes per day
Travel time to patient	In minutes per patient
Administration of subcutaneous chemo	In minutes per patient

Supplementary information - Table C: Wage costs per minute

Profile	Unit costs (Euro 2019 prices)	Source
Hospital care: nurse	€0.77 per minute	Wage rates of hospitals (average of the oncology day care units of the three hospitals)
Home care: nurse	€0.72 per minute	Wage rates home nurses (average of two home nursing organizations)

Supplementary information – Table D: Time per activity, in minutes, based on time registrations

Average time per activity (in minutes)	SOC – Administration in hospital						HH Model 1 Blood draw and symptom control at home				HH Model 2	
	Intravenous treatment 1 product (1)		Intravenous treatment, multiple products (2)		Subcutaneous treatment (3) (4)		Intravenous treatment 1 product (5)		Intravenous treatment, multiple products (6)		Subcutaneous treatment At home (7) (8)	
	n = 29		n = 15		n = 2		n = 99 *no distinction in process at home*				n = 15	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nursing activities per day care visit												
Blood draw + symptom control in the hospital (1)	20.0	6.6	19.0	7.4	14.6	1.1	-	-			-	-
Blood draw + symptom control at home by home nurse	-	-	-	-	-	-	32.9	8.8	32.9	8.8	-	-
Administration of chemo + follow up	10.7	6.8	18.0	9.1	7.2	2.1	In hospital (3): 10.7	6.8	In hospital (3): 18.0	9.1	25.9	4.4
Other direct care time of the nurses in the day care unit	18.7	12.9	27.1	23.6	8.2	0.8	In hospital (3): 18.7	12.9	In hospital (3): 27.1	23.6	-	-
Indirect care time of the nurses in the day care unit	35.6	19.8	55.5	35.1	24.7	4.6	In hospital (3): 35.6	19.8	In hospital (3): 55.5	35.1	-	-
Planning + follow up in home nursing	-	-	-	-	-	-	14.6	8.4	14.6	8.4	-	-
Total time (hospital + home)	**84.9**		**119.7**		**54.7**		**112.5**		**148.1**		**25.9**	**4.4**
Coordination, logistics and administration												
Total time	*Calculated as Total cost of coordination, logistics and administration on the day care unit / # day patients*						**13.5 (2)**		**13.5 (2)**		**12.0 (2)**	
Travel time												
Pick up treatment, (in minutes / round)	-	-	-	-	-	-	-	-	-	-	7.7	2.5
Transport to patient	-	-	-	-	-	-	14.4	6.6	14.4	6.6	16.3	8.3
Transport to hospital (in minutes / round)	-	-	-	-	-	-	16.5	4.5	16.5	4.5	22.4	6.1
Avg. # patients/round	-	-	-	-	-	-	6.5	-	6.5	-	2.0	-
Total time							**16.9**		**16.9**		**31.4**	

(1) As there is no difference in the process of drawing blood and symptom control between Intravenous Chemo 1 product and multiple products, the average of 19.6 minutes will be used in the cost calculation.
(2) Added based on interviews; no s.d. available.
(3) These activities remain the same in HH1, as only the blood draw and symptom control is performed at home

Supplementary information – Table E: Material costs

Type of cost	**Cost per patient visit**	**Source**
Material for blood draw in hospital	€8.76	Financial administration of two hospitals (Average)
Material for blood draw at home (paid by the hospitals in the pilot)	€9.00	Financial administration of two hospitals (Average)
Material for administration of one chemo product/day	€1.37	Financial administration of two hospitals (Average)
Material of administration of multiple chemo products/day (1)	€6.51	Financial administration of two hospitals (Average)
Material for administration of subcutaneous treatment	€0.41	Financial administration of two hospitals (Average)

(1) Assuming two products per administration, the number of products per administration can also be three or four.

Supplementary information – Table F: Average material cost per care pathway

Material cost	SOC – Administration in hospital				HH1 Blood draw and symptom control at home		HH2 Subcutaneous treatment at home	
	Intra-venous treatment 1 product 1	Intra-venous treatment, multiple products 2	Sub-cutaneous treatment Azac-itidine 3	Sub-cutaneous treatment Borte-zomib 4	Intra-venous treatment 1 product 5	Intra-venous treatment, multiple products 6	Aza-citidine 3 visits in hospital, 4 at home 7	Borte-zomib 1 visit in hospital, 3 at home 8
Blood draw	€8.76	€8.76	€1.25 (1)	€2.19 (1)	€9.00	€9.00	€1.25 (1)	€2.19 (1)
Administration of chemo								
- At home							€0.41 (2)	€0.41 (2)
- In hospital	€1.37	€6.51	€0.41	€0.41	€1.37	€6.51		
Average cost	€10.13	€15.27	€1.66	€2.60	€10.37	€15.51	€1.66	€2.60

(1) Average cost per cycle: Care Pathway 3 and 7: Average cost of one visit, 7 administrations of chemo per cycle, one blood test per cycle, performed in the hospital = €8.76/7 = €1.25; Care Pathway 4 and 8: Average cost of one visit, four visits per cycle, one blood test per cycle = €8.76/4 = €2.19

(2) Price is equal at home and in hospital

Supplementary information – Table G: Revenues per visit

Revenues per visit (in minutes)	SOC – Administration in hospital			HH Model 1 Blood draw and symptom control at home		HH Model 2
	Intravenous treatment 1 product 1	Intravenous treatment, multiple products 2	Subcutaneous treatment 3 4	Intravenous treatment 1 product 5	Intravenous treatment, multiple products 6	Subcutaneous treatment At home 7 8
Hospital	€124.1	€166.1	€124.1	€124.1	€166.1	€124.1
Home nursing				€33.6 (1)	€33.6 (1)	€5.3 (2)

(1) For blood draw and symptom control at home, the administration of the intravenous treatment is performed in the hospital the next day.

(2) For the administration of the subcutaneous treatment at home

General discussion

The objective of this research was to learn how the VBHC principles can be implemented in practice in order to improve the care delivery in the Belgian healthcare system. Therefore, in the introduction, the concept of VBHC and different implementation frameworks were described. In summary, the recommendations for implementing VBHC highlighted several crucial aspects: (1) measuring outcomes, costs and variation in healthcare, (2) benchmarking and setting up learning communities, (3) integrating care delivery over the full cycle of care, and (4) including the patients' perspective in shared decision-making and quality improvement.

In this PhD research, we wanted to learn how we can bring these aspects into practice through concrete case studies. The problem definition of this PhD research was formulated as "How can we measure costs and outcomes of care and how can we use this information to improve outcomes and costs?" This problem definition was divided into different research questions. In this general conclusion, we will formulate an answer to each research question. This is followed by a discussion section on different aspects of VBHC that were not treated in this PhD research and need further attention in future research. Finally, we formulate a general conclusion.

RQ1: How can we measure outcomes of care?

Clinical and patient-reported outcomes are used to evaluate the quality of care. While clinical outcomes are reported by the care team, PROMs are reported by patients to evaluate the perceived effects of a disease or treatment on symptoms, functioning, and health-related quality of life. On an individual patient level, the measurement of outcomes of the delivered care can support shared decision-making, facilitate communication between patients and clinicians, help to identify problems, reduce unnecessary appointments, and improve patient outcomes. At a population level, it allows healthcare providers to benchmark treatment effects against their peers by identifying and learning from best practices and improving the care they deliver. To support the collection and benchmarking of clinical outcomes and PROMs, multiple software programs and data platforms were developed.

In the first research question, reported in the first chapter, we evaluated whether it is feasible to collect clinical and patient-reported outcomes and to implement a follow-up of these outcomes for a specific care pathway. Therefore, the implementation of outcome measurement for lung cancer patients in a large Belgian hospital, AZ Delta was evaluated. Inspired by the principles of VBHC, this department standardized care pathways, defined outcomes and implemented a digital platform for the collection of some specific clinical outcomes and PROMs for lung cancer patients. Also, a follow-up of the clinical outcomes and PROMs by the multidisciplinary care team and with patient involvement was put in place.

The results provided several important lessons when measuring outcomes of care pathways and using it for improving care. First, the digital health solution needs to be integrated into healthcare team practices, and responses should be appropriately managed. Second, it is important that a multidisciplinary care team is put in place to respond to patients' clinical, psychological, palliative, financial, and family-related concerns. Third, leadership is an important enabler in the implementation process. Fourth, we recommend using a digital tool, rather than reporting PROMs on paper. Such a tool should enable (1) the collection of PROMs and clinical outcomes, (2) the visualization of

these data using dashboards, and (3) the provision of feedback to clinical teams and patients. Moreover, the digitally reported data can be used for further research, quality evaluation of the care process, and improvement cycles.

We did not investigate the clinical implications and the responses to the questionnaires. These aspects were investigated on the same population in AZ Delta by Demedts et al. (2021), who concluded that the implementation of VBHC is beneficial in daily clinical care for lung cancer patients. Patients in the care pathway had significantly fewer ED visits (3.5% vs. 4.8%, p 0.04) and a shorter length of stay at the day clinic (2.5 h vs 4.1 h, $p < 0.05$) than the SOC. In Stage IV lung cancer patients, overall survival was significantly higher in the care pathway (447 days (95% CI 379–663)) compared to the SOC (286 days (95% CI 191–400)) ($p = 0.025$).

Benchmarking of outcomes is also an important aspect in implementing VBHC. To enable benchmarking, the clinical and patient-reported outcomes collected for lung cancer patients in AZ Delta were also collected in ZOL, another large Belgian hospital. Based on these data, a comparative analysis between the outcomes was conducted in the two hospitals, outside of this PhD research. This comparison revealed that a decrease in the admission time after surgery in one of the two hospitals is possible. Also, the number of stays in the intensive care unit in the last 30 days of life was lower in one hospital than in the other. Based on these comparisons, improvement actions were defined. The objectives of these actions are to achieve a mean hospital stay of five days for lung surgical procedures and to avoid admission in an intensive care unit in case of advanced lung cancer.

To draw more general conclusions on the use of PROMs and PREMs, KCE (Desomer et al., 2018) conducted an evaluation on the use in patient care and policy. They made a distinction at three levels of potential added value: the micro or individual patient level to support shared-decision making, the meso- or institutional level to drive healthcare quality improvement initiatives, and the macro level on population health monitoring, reimbursement decision-making, and healthcare performance measurement. In reviewing the literature, they concluded that most research focuses on the use of PROMs in clinical care as a tool to support clinical management and improvement of quality of care. Most research has focused on oncology care. At this level, PROMs help to improve the communication between patients and clinicians and within the multidisciplinary care team and it helps to discuss symptoms and outcomes that are otherwise not discussed. For the meso- and macro-levels, however, they were not able to draw conclusions based on the literature due to a lack of primary studies. They advise that PROMs and PREMs can support the shift towards patient-centered care and to enable a better understanding of outcomes and effectiveness of health interventions and recommend a stepwise introduction of PROMs and PREMs.

RQ2: How can we measure the costs of care?

Measuring the costs of care and making it transparent to clinical teams is another key component of VBHC when attempting to relate the costs to the quality of the care delivered. Therefore, our second research question evaluated how we can measure the costs of care.

The goal of this research question was to select a method that makes it possible to allocate costs on a patient and pathology level from the perspective of the providers, with a focus on hospital costs. The prerequisite was that the method should be reproduceable and

automatable in order to allow benchmarking between hospitals. Therefore, it should make as much use as possible of the available information in the hospital information systems.

In answering this second research question, we concluded that top-down micro-costing of all costs to a DRG can be selected as the most appropriate methodology to allocate costs to a cost object.

The cost calculation method described consisted of seven steps (see Chapter 2 for more details about the steps):

1. Standardization of cost categories and cost centers over hospitals to enable comparability
2. Step-down allocation of overhead cost centers to medical cost centers
3. Collection of direct pharmacy costs on a patient level
4. Collection of detailed activity information on a patient and activity level
5. Calculation of a unit cost per activity
6. Calculation of costs per patient
7. Aggregation on a DRG and service level

To calculate the unit cost per activity, allocation keys were defined for each cost center (see Chapter 2 for the detailed methodology). This unit cost was calculated for each medical department, such as the surgical ward, radiology-NMR, etc. and for each category, such as staff costs, material costs, depreciations, and overhead costs.

RQ3: Benchmark of processes and costs of care in Belgian hospitals

The third research question focused on the crucial role that benchmarking plays in implementing VBHC. The objective of this research question was to examine the feasibility of establishing a benchmark among hospitals and to identify the challenges and lessons learned. To achieve this, a research project was initiated to compare outcome, process, cost, and revenue data from hospitals in the Flemish region.

Chapter 2 presented the findings from a first pilot study in setting up the benchmark, which involved six Belgian hospitals and focused on process and cost data from 2019. This pilot focused on the resource use and costs of inpatient stays on a patient and pathology level within the hospital and compared to other hospitals from a providers' perspective. It was a multicenter study, and the sample was composed of all hospitalized patients. This sample of hospitals consisted of two large hospitals (revenue in 2019 > €250 million), two medium-sized hospitals (revenue in 2019 between €100 and €250 million) and two small hospitals (revenue in 2019 < €100 million). Outcome data were not yet included in this first pilot. The long-term goal of this research is to repeat this benchmark yearly and gradually improve and expand it, also including outcome data.

This study involved a full costing analysis, which means that all hospital costs were allocated to a patient visit. The overall method used in the benchmark was top-down micro-costing. The costs were calculated at a detailed patient and visit level. The costs were then aggregated based on the patient's diagnosis and illness severity, using the Diagnosis-Related Group (DRG) and Severity of Illness (SOI) classification system. This system groups hospital cases based on their clinical characteristics and expected resource utilization. In Belgium, every hospitalization and day care visit is assigned a DRG and SOI through a grouper program that takes into account the patient's diagnoses, procedures, and demographic factors.

In this study, a reproducible and automatable method for calculating costs was set up in order to enable benchmarking between more hospitals in the future. To achieve this goal, the available accounting and activity information from hospital information systems was used for the year 2019. However, these data were initially not intended for this purpose.

Establishing a benchmark to assess costs per patient stay and per DRG across multiple hospitals was possible. However, due to the absence of DRG or other comprehensive registration for the entire care pathway, the costs could only be consolidated per patient stay, limiting the ability to gain an overview of all activities and costs throughout the entire care pathway.

This benchmark was presented to each hospital in the form of two dashboards: (1) a comprehensive dashboard offering a detailed analysis of the activities and costs per patient stay, DRG, and service within their own hospital; and (2) an aggregated benchmark dashboard with activities and costs per stay (per DRG and severity), in which the hospitals were anonymized. The results were visualized using Microsoft PowerBI, while the models were programmed in R. Unfortunately, the costs could only be aggregated per patient stay, as no DRG or other registration was available for the full cycle of care.

Several attention points were formulated in relation to the benchmark. Standardizing the accounting information across different hospitals was a significant challenge in the benchmarking process. A second attention point deals with the accuracy of the cost calculation. By making use of unit costs per activity, differences between patients (for example, in care time per day) are leveled out. A more precise cost calculation method on a patient level is bottom-up costing by performing time registrations and costs of material registrations for each patient. However, this can require considerable time and effort and it is important to make a judgement on how accurate cost estimates need to be within a given study. Third, the costs of depreciations vary among hospitals: hospitals that recently constructed new facilities have higher depreciations. Fourth, nursing costs are a significant component of hospital costs, and accurate allocation is essential. In our case study, the unit costs of the wards were calculated based on the number of patient days weighted for care intensity, based on the care intensity registrations demanded by the government in each hospital during several weeks a year. Fifth, the use of surgical time as a proxy for resource consumption in operating rooms was found to have certain limitations. Sixth, activity data registrations are performed according to regulations mandated by the government. However, the interviews revealed that there are still differences between hospitals in the interpretation of these regulations.

RQ4: What can we learn from benchmarks and how can it improve care delivery?

Learning from each other and setting up improvement cycles is a crucial step in improving value. The goal of the third research question was to implement a benchmark, and in the fourth research question we wanted to learn whether this benchmark helped to improve the care delivery. This research question is also included in Chapter 2. Therefore, we performed interviews with one or two people in each participating hospital.

The hospitals received the benchmark at the end of June 2022. The interviews were conducted in January and February of 2023, so the hospitals already had six months of time to work with the benchmark. The interviewees identified three areas of learnings from the benchmarking process: comparability of results, utilization of results, and improvement ideas.

At the time of the interviews, only one of the six interviewed hospitals had already used the insights of the benchmark for improvement projects. In that hospital, analysis per department and per specialism were made. The results were presented to the board of directors, the management committee and the medical department heads. Also, detailed analysis per specialism were made and discussed by the medical director with every medical department head. Based on these discussions, actions were defined. This hospital learned from the benchmark that the improvement potential is the largest in the OR. This resulted in a more profound analysis of the OR occupation data per specialism outside of this research and improvement actions were implemented.

RQ5: What is the impact of optimizations in the care process on costs and outcome?

The aim of the fifth research question was to learn, in a specific case study, what impact optimizations in the care process have on costs and outcomes.

Therefore, we investigated the onco@home project, in which two home hospitalization (HH) models were implemented and compared to the standard ambulatory hospital care process (SOC). In the SOC, the patient arrives at the day hospital, where all necessary medical procedures are conducted. These include sample collection for blood analysis and anamnesis by an oncology nurse, blood analysis, data interpretation by the physician, consultation with the physician, preparation and administration of chemotherapy and follow-up. In a first HH model (HH1), the blood draw and monitoring prior to intravenous therapy was performed by a trained home nurse at the patient's home the day before the visit to the day hospital instead of in the hospital the day itself. This care model was implemented by three Belgian hospitals and three home nursing organizations (two home nursing organizations participated in the cost study). In a second HH model (HH2), the administration of two subcutaneous treatments was partly provided at home instead of in the hospital. This was implemented by one hospital. To determine whether HH helps to maximize value, it is important to create insights in the outcomes and costs of HH compared to the standard ambulatory hospital care.

We could conclude that the implemented HH models are feasible and safe, that a large majority of patients are highly satisfied with HH, and that it has a positive impact on their quality of life. However, our research revealed that cost of home nursing for these specific HH models is higher than hospitalization and that current funding from Belgian NHI is insufficient to organize HH. As a result, HH for oncology patient is still limited in Belgium. Reimbursement will be a key success factor in the uptake of HH. Therefore, starting from July 1, 2023, the government decided to improve the reimbursement for home hospitalization.

Other aspects of VBHC and future research

In this PhD research, we wanted to learn how we can bring the VBHC components into practice by studying concrete case studies. For some aspects of VBHC, methodology and recommendations were formulated. However, several aspects of VBHC received less attention. In this final chapter, we want to give an overview of aspects we did not treat in this PhD and give possibilities for future research.

Benchmark on costs and outcomes

The third research question of this PhD focused on the crucial role of benchmarking in implementing VBHC. The objective of this research question was to examine the feasibility of establishing a benchmark among hospitals and to identify the challenges and lessons learned. To achieve this, a research project was initiated to compare outcome, process, cost, and revenue data from hospitals in the Flemish region.

Chapter 3 presented the results of an initial pilot study that encompassed six Belgian hospitals. This study concentrated on examining process and cost data from 2019. Beyond the scope of the PhD research, an extension of this benchmark was carried out using data from 2021 and 2022. The expansion involved 11 hospitals with data of 2021 and 13 with data of 2022 and incorporated the revenues generated by the care delivered into the benchmarking analysis. This enhanced approach enabled the comparison of processes of more hospitals and the calculation and comparison of the margins associated with each service, patient visit, and pathology.

Outcomes were not yet included in the benchmark, but the data model created for each hospital contains pseudonymized data on costs and processes of all ambulatory care in the hospital and of all hospitalized and day-care patients. Since all patient visits are included in the database, this data model could be linked to other systems and databases, such as electronic health records, clinical or patient-reported outcomes or quality registries, which makes the inclusion of outcome indicators in the data model per hospital and subsequently on an aggregated level in the benchmark possible. Also, an international comparison of costs, outcomes and activities on a pathology level would be a very interesting area of further research. Common data models like the Observational Medical Outcomes Partnership (OMOP) are being increasingly created to provide standardized vocabularies to facilitate this comparison.

In Flanders, Belgium, and on an international level, several broader initiatives on the registration and public reporting of benchmark information of outcomes have been established. However, none of them link outcomes to costs. The Flemish Institute for Quality of Care (Het Vlaams Instituut voor Kwaliteit van Zorg – VIKZ) collects outcomes on patient safety, clinical outcomes on a set of pathologies (breast cancer, lung cancer, stroke and rectum cancer) and PREMs. These outcomes are made publicly available on the website www.zorgkwaliteit.be. PROMs are not included in these registrations. Moreover, hospitals affiliated with the Vlaams Ziekenhuisnetwerk KU Leuven VZW (VZN) gather outcomes data for various pathologies. VZN establishes benchmarks and iterative improvement cycles based on the collected data. These outcomes have not been subject to public reporting thus far. As indicated by the VZN website, 31 hospitals are actively participating in these benchmarking initiatives (VZN, 2023). In addition, the Belgian federal government has initiated a pay-for-performance program, requiring hospitals to furnish information regarding accreditation, clinical registration, quality labels, and patient

experiences in order to secure funding (FOD Volksgezondheid, 2023). Furthermore, several Belgian hospitals have taken specific measures to gather clinical and patient-reported outcomes for particular pathologies (Desomer et al., 2018). At an international level, the OECD aggregates quality indicators from member countries, including Belgium, to facilitate comparisons of healthcare system performance and encourage the alignment of outcomes data across member states (OECD, 2023b). Similarly, ICHOM pursues analogous objectives by developing standardized sets of international outcome indicators for various medical conditions, promoting cross-border comparisons of outcomes (ICHOM, 2022).

It would be interesting for future research to explore the integration of quality data collected from these diverse frameworks into the benchmark.

Financing model: Move to bundled payments for care cycles

One of the components Porter and Lee (2013) described to implement VBHC is to move to bundled payments for care cycles. They argued that the common payment models in healthcare, like global capitation and fee-for-service payments, do not reward improvements in the value of care. A global capitation, a single payment to cover all patient's needs, rewards providers for spending less but not specifically for improving outcomes or value. In a fee-for-service system, where providers receive a payment for each service delivered, providers are rewarded for increasing volume but not for increasing value. According to Porter and Lee (2013), a bundled payment that covers the full care cycle for acute medical conditions, the overall care for chronic conditions for a defined period of time or primary and preventive care for a defined patient population is best aligned with delivering value. These bundled payments should be adjusted for severity to guarantee that providers are accountable for avoidable complications and reporting of outcomes should be mandatory.

In Belgium, the exploration of innovative financing systems such as bundled payments for the full cycle of care is included in the plan for the reform of the hospital organization and financing by Vandenbroucke (2022), p.12:

> *"Over time, we need to take further steps toward funding that addresses continuity, coordination and integration of care. Innovative financing systems such as bundled payment or population financing should be explored. Bundled payment refers to a single payment for all care related to the treatment of a patient with a specific condition and that for a specific period of time. In this process, the entire pathway is funded. This funding relates to a particular type of pathology. The total available budget is determined for a number of patients and is managed by a single healthcare agency (as the case may be, primary care or the hospital)"*

Other countries have already gained experience in the implementation of bundled payment models. Struijs et al. (2020) evaluated the empirical evidence of bundled-payment models on quality of care and medical spending. A bundled payment was defined as an episode of care for a medical condition or treatment including services of multiple providers. The authors identified 23 initiatives in eight countries and provided evidence that bundled-payment models have the potential to reduce medical spending while having a positive impact or no impact on quality of care. The a-priori-assumed effects of bundled payments, like closer collaboration among providers, better coordination of care, reduction of overuse of care and greater use of preventive services, were supported by multiple evaluations. Challenges already described in literature are the difficulty of defining quality criteria,

privacy laws and the difficulty of information-sharing, which patients to include in the bundle, income loss for some care professionals, and potential limits on patients' freedom of choice (Steenhuis et al., 2020).

The Belgian government can learn from these experiences in implementing bundled payment models. Further research can be performed on success factors and challenges of implementing bundled payments and on the impact of the implementation on quality of care, cost of care, and coordination of care.

Costs of the full cycle of care

In this PhD research, a benchmark with six hospitals was set up and costs and processes per DRG per stay and service were included in this benchmark. It will be important for future research to calculate and benchmark the costs over the full cycle of care in the hospital, as well as in ambulatory care outside the hospital. This will make it possible to understand, compare, and improve the full care process, as well as the comparison of costs of new therapies versus the Standard of Care, or of treatment alternatives.

In this regard, an important policy recommendation was made in this PhD research. In Belgium, all hospitalizations and day-care visits are categorized by a DRG and SOI. As a result, a cost could be calculated per patient and aggregated per DRG and SOI. Unfortunately, this DRG-registration is not set up over the full cycle of care. For each visit to the hospital, a new DRG is created, which makes it challenging to accurately calculate the costs of the full cycle of care. In contrast, the Netherlands has implemented a DBC-system that provides gradual records of all activities performed during the full cycle of care within the hospital, allowing for more accurate cost calculation (NZA, 2020). Also, DBCs were created for specific care pathways in ambulatory care, such as diabetes, COPD, and cardiovascular risk management. Also, in the United Kingdom, the NHS has set up PLICS to calculate patient level costs (NHS, 2023a). Furthermore, data collection in the UK has been designed to link costs of Emergency care, Admitted patient care and Outpatients costs to Hospital Episode Statistics data at record level to permit analysis such as cost by primary diagnosis (NHS, 2023b).

Given the Belgian government's intent to switch to a prospective all-inclusive flat rate per pathology for hospital care based on justified costs, it will be necessary to establish a registration system that includes both pre- and post-hospitalization activities and costs within the hospital setting (Vandenbroucke, 2022). Additionally, to incorporate the costs associated with ambulatory care outside the hospital, there is a need to establish the capability to link the hospital care to ambulatory care on an individual patient level and, ideally, to specific diagnoses, covering the entire cycle of care.

Appropriate care

In the broader definition of VBHC of the EXPH, discussed in the introduction of this PhD dissertation, the delivery of appropriate care was included as one of the four value pillars. It is important that patients receive the appropriate care that aligns with standards, best practices and the specific needs of an individual patient. However, the OECD presented alarming data on inappropriate care in their report "Tackling Wasteful Spending on Health", estimating that one in 10 patients is affected during treatment by preventable errors and that more than 10% of hospital expenditures is used to correct these errors (OECD, 2017).

Some steps are already being taken to gain insights into the appropriateness of care. In Belgium, the website 'For a healthy Belgium' provides data on appropriateness of care, giving insight into variations on the use of antibiotics, medical imaging exams, etc. Also, the OECD report entitled 'Health at a Glance' (OECD, 2023b) delivers data on variations between member countries. Also, specific OECD reports, like 'EU Country Cancer Profile: Belgium 2023' (OECD, 2023a) give insights into overuse and underuse compared to other OECD countries.

Learning from these data and setting up improvements will be important. In this PhD research, we built up a benchmark with data on processes and costs of care. We did not investigate questions regarding whether each intervention is appropriate. In future research, it could be insightful to bring together learning communities of care-takers and patients on specific disease groups to discuss the total care pathway and to evaluate what preventive measures can be taken to avoid the intervention and to discuss what the optimal care pathway is: which steps can be taken by first line, digital support, etc.

The patients' perspective

Recent research has pointed out the importance of including the patients' perspective in VBHC. According to the report of the EXPH on VBHC (Expert Panel on effective ways of investing in Health, 2019), healthcare must switch from a "disease-centered" approach to a "person-centered" approach. Patients should be active partners in their care, with their needs, goals, and preferences driving all levels of treatment. This involves integrating patient-centered practices into research, clinical processes, organizational structures, and governance. Also, Berwick (2016) sees a shift to co-design and person-centered care, where clinicians should learn to ask "What matters to you?" instead of "What is the matter with you?"

Patients' participation can manifest at three distinct levels. Firstly, patients should be encouraged to participate in decisions about their own care, by practices such as shared decision-making, or by discussing information from PROMs with their care givers. Secondly, patients should be engaged in quality improvement of the care process. At the third level, patients' engagement extends to policy shaping within the governmental framework, achieved through their representation in patient organizations. This level of participation contributes to the development of healthcare policies.

The case study on lung cancer patients is an example of the first level. The PROMs included both generic quality of life questions and specific questions related to the condition, such as fatigue and psychological concerns. In this case study, some good practices were described, such as having a process to follow-up the responses by a multidisciplinary care team, leadership of doctors and a digital tool to collect data and to provide feedback. On the second level, care organizations are taking steps to include patients' experiences in quality improvements. In further research, it will be interesting to learn from these experiences to further improve care delivery from a patient's perspective.

Primary and secondary use of health data

The presence of a data platform that enables sharing of data is an important pillar in delivering VBHC. This element was already included in the strategic agenda of Porter and Lee (2013). Since then, several important steps have been taken in Europe and in Belgium. The European Health Data Space (EHDS) was launched in May 2022 to set out a common EU framework that aims to empower individuals to have increased digital access and control of their electronic personal health data and to provide the secondary use of health data for research, innovation, public health, policy making and regulatory activities. In Belgium, several important projects are in the pipeline. First, the Belgian Integrated Health Record (BHIR) will play an important role in the primary use of health data. In addition, the Belgian Health Data Agency (HDA) was founded in 2023 to facilitate the secondary use of electronic data by giving access to electronic health data for research.

However, those initiatives are still in their infancy and data on outcomes to connect to process and cost data are not publicly available in Belgium. It is an important policy recommendation to take the actions foreseen by the Belgian federal government on the secondary use of data.

Conclusion

VBHC was presented as a fundamentally new strategy with the ambitious goal of transforming healthcare and delivering high value care while optimizing costs. This vision demands a comprehensive overhaul of healthcare practices and strategies to realize its objectives.

Throughout this PhD research, we tried to contribute to this vision by exploring methodology on some essential building blocks. The first research question focused on the measurement of patient-reported and clinical outcomes of care pathways and the use of these outcomes in clinical practice. In the second research question, methodology was created to calculate costs of care. In the third research question, this methodology was applied to a pilot study of six hospitals and costs per activity, patient and DRG were calculated. The fourth research question focused on the learnings from the benchmark and how it can improve care delivery. The last research question focused on the impact of optimizations in the cancer care process on outcomes and costs.

Nonetheless, while our research has contributed valuable insights, it is evident that the journey towards full VBHC implementation is far from complete. Several avenues for further investigation have emerged, underscoring the complexity of achieving VBHC's comprehensive vision. The recommendations formulated in the discussion chapter of this PhD research offer several areas for further research. The establishment of outcome and cost benchmarks, comprehensive calculation of the complete care cycle costs, integration of patient perspectives, development of appropriate financing models, and the governance of data are all vital aspects requiring further exploration.

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